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PHYSICS
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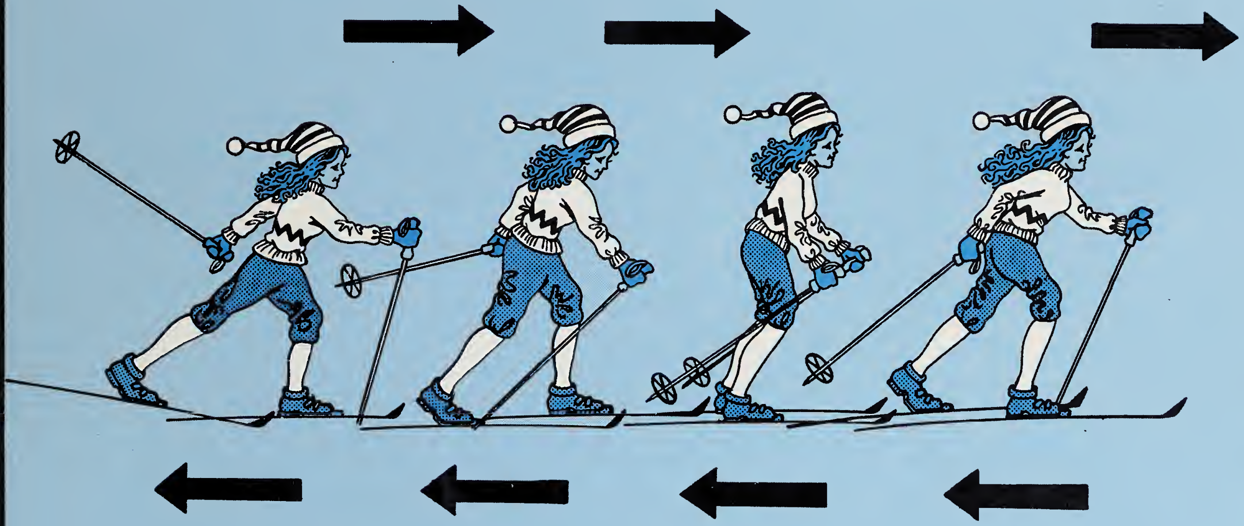

MOTION

Alberta Distance Learning Centre
Barrhead, Alberta

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Physics 10

Lessons 1-9

Distance
Learning

Alberta
EDUCATION

Physics 10
Student Module
Lessons 1-9
Alberta Distance Learning Centre
ISBN No. 0-7741-1102-X

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The textbook to be used in this course is the following:

Paul, Peirce and Stief. Physics: A Human Endeavour
Unit 1 MOTION. First edition.
Holt, Rinehart, and Winston of
Canada, Limited. Toronto. 1977

The course consists of 12 lessons and has a credit value of three. In order to be eligible to receive the three credits, 12 lessons and a final test must be completed and must receive appropriate gradings. See the evaluation sheet enclosed with this course for information concerning the distribution of marks.

The course is arranged in two major sections:

(1) a core section, consisting of Lessons 1 to 9 (Mod. X);
(2) an elective section, consisting of three lessons (Mod. A or B).

The core section covers the basic ideas concerning the motions of bodies. The elective section must be selected by the student. In order to obtain the elective section that you want, please complete the selection form that follows the first lesson, and send it in with your first lesson.

When submitting your lesson work you should send in all pages on which you do work. The only exception is "self-check" work.

Laboratory work is an important part of the course. Any lesson submitted without the required laboratory work is returned incomplete. There is no laboratory kit required for this course. The experiments are arranged such that a student can get the supplies easily from the house or the market. The following is the list of supplies required in each experiment.

Experiment #1: Study of Falling Objects

Cylinder of water (pail or bucket)
Marbles or steel spheres (small rocks or pebbles)

Experiment #2: To find the average speed of an object

Stop watch (wrist watch with seconds-hand)

Experiment #3: To find the acceleration of a uniformly accelerated body

Flat board (Dining table or coffee table)
Cylinderical object (glass vial, rolling pin or tin can)
Stop watch (wrist watch with seconds-hand)

Experiment #4: Measuring acceleration of a freely falling or freely rolling body

A: Flat board (coffee table or dining table)
Newsprint (old newspaper)
Steel ball (marble or cylinderical can)
Small area boards (books)

or

B: Long flat board, golf ball, or hard rubber ball and water.

Experiment #5: Some effects of Inertia

Marble
a piece of paper
a pencil or pen about 15 cm long
a marker (a short pencil or the cap of pen).

Elective A: Students are provided with various parts of the Astrolabe and they assemble the parts to construct the Astrolabe and make astronomical observations.

Elective B: This elective has no laboratory work.

ADVANCE NOTICE CONCERNING TESTING AND COURSE EVALUATION

1. In order to be recommended for credits for Physics 10 you are required to write a supervised test set by the Alberta Correspondence School before registration expires. A portion of the final mark will be based on your course work, as evaluated by the teacher of the Alberta Correspondence School. If the final mark differs substantially from the year's work, the teacher will use discretion in balancing the composition of the marks in order to arrive at a fair assessment of achievement in the course. Appeal papers will be available to all students whose registration has not expired.

2. (a) **Classroom students**

Those who are in attendance in school in Alberta and who are supplementing their school programs by taking one or more correspondence courses.

A student attending school does not submit an application for the final test. Test papers are sent automatically to the principal during the school year or at the end of August for writing during the first week of September. At least ELEVEN SATISFACTORY LESSONS out of the twelve to be submitted must be received by the Alberta Correspondence School before a test paper is mailed to the principal. However, all twelve lessons should be submitted before the test is written.

The principal is in charge of scheduling final tests and all questions about scheduling should be directed to the principal.

If a test is not written before expiry date of registration, the course is considered incomplete for the school year for which the student registered.

(b) **Non-classroom students**

Those who are studying exclusively by correspondence, and are not registered in any subjects in an Alberta classroom.

To obtain course credits, non-classroom students must complete all required lessons and write the final test before the expiry date of registration. Information about expiry dates is given in the Information Bulletin which a student receives before filing an application for a correspondence course.

The application for the final test is sent out when the corrected Lesson 6 is returned to the student and the student submits the application with Lesson 10. The test is sent out after **ELEVEN SATISFACTORY LESSONS**, out of the twelve to be submitted, have been received by the Alberta Correspondence School. However, all twelve lessons should be submitted before the test is written.

If a test is not written before registration expires, the course is considered incomplete for the school year during which the student registered.

NOTE: For the purpose of writing final tests, students who live outside Alberta come under the same regulations as those in category (b).

HOW YOUR LESSONS WILL BE GRADED

Your standings on the lessons will be indicated by means of letter gradings on the following basis:

Letter Gradings	Range of Scale
A	80 - 100%
B	65- 79%
C	50 - 64%
D	40 - 49%
F	0 - 39%

We wish you success and enjoyment in this course.

PHYSICS 10

Evaluation and Grading

The final mark will be obtained in the following manner:

Final Test	70%
Lessons	30%
	100%

For the lesson portion to be considered in the calculation of your final mark you will need to obtain at least 40% on the final test. Please be aware that all lessons must be submitted before the final test is written. Course work received by the Alberta Correspondence School after the test is written will not count toward your final mark.

Also note that a passing mark of 50% must be obtained to receive credits in the course.

Note Regarding the Final Test in Physics 10

The final test in Physics 10 is closed book, the formulas on the back of this sheet will be given in the exam. You may also use nonprogrammable calculators in which the memory has been cleared. This test also covers the elective. The test is two hours in duration and the format is similar to Lesson 9. A ruler and protractor should be brought for use in the exam.

Kinematics

$$\vec{v}_{ave} = \frac{\vec{d}}{t}$$

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$v_f^2 = v_i^2 + 2ad$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

Dynamics

$$\vec{F} = m\vec{a}$$

$$\vec{F}t = m\Delta\vec{v}$$

$$\vec{F}_g = m\vec{g}$$

$$g \text{ or } a_g = 9.8\,\frac{m}{s^2} = 9.8\,\frac{N}{kg}$$

Fluids

$$P = hDa_g$$

$$F = DVa_g$$

$$P = \frac{F}{A}$$

$$D = \frac{m}{V}$$

$$d_R = \frac{D_s}{D_w}$$

$$V = \pi r^2 h$$

$$V = hA$$

Momentum & Energy

$$\vec{p} = m\vec{v}$$

$$P = \frac{W}{t} = \frac{E}{t}$$

$$W = Fd$$

$$E_k = \frac{1}{2}mv^2$$

$$E_p = mgh$$

Waves & Light

$$v = f\lambda$$

$$T = \frac{1}{f}$$

$$n_{12} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Heat

$$h = mc\Delta t$$

Sound

$$E = \frac{E_0}{d^2}$$

$$f = \frac{1}{2l}\sqrt{\frac{T}{m_l}}$$

A LESSON RECORD FORM MUST BE COMPLETED FOR EVERY LESSON SUBMITTED FOR CORRECTION, AS ILLUSTRATED BELOW

A Lesson Record form with the **correct** label attached **must** be enclosed with **every lesson** submitted for correction, as illustrated below.

Correct use of these labels will ensure prompt processing and grading of your lessons.

The enclosed **Lesson Labels** must be checked for spelling and address details.

Please advise the Alberta Correspondence School promptly of any changes in name, address, school, or any other details and we will issue a revised set of labels. Your file number is permanently assigned and **must** be included on all correspondence with the Alberta Correspondence School. If the proper label and Lesson Record Form is not attached to each lesson as indicated it will delay your lessons being processed and credited to you.

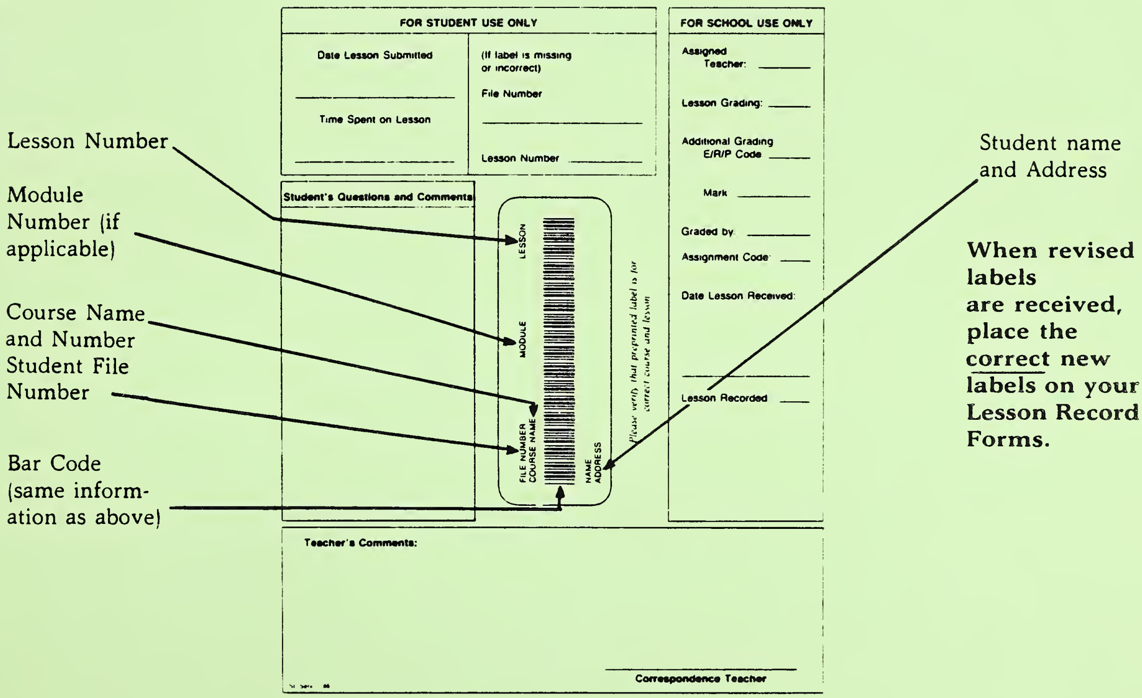
Lesson labels are to be attached to the **lesson record forms** in the space provided for student name and address.

Check carefully to ensure that the **subject name, module number** and **lesson number** on each label corresponds exactly with the lesson you are submitting.

Labels are to be **peeled** off waxed backing paper and **stuck** on the lesson record form.

Only **one** label is to be placed on each lesson.

LESSON RECORD FORM



FOR STUDENT USE ONLY

Date Lesson Submitted

Time Spent on Lesson

(If label is missing or incorrect)

File Number

Lesson Number

Student's Questions and Comments

FOR SCHOOL USE ONLY

Assigned Teacher:

Lesson Grading:

Additional Grading E/R/P Code

Mark

Graded by

Assignment Code

Date Lesson Received:

Lesson Recorded

Teacher's Comments:

Correspondence Teacher

Lesson Number
Module Number (if applicable)
Course Name and Number
Student File Number
Bar Code (same information as above)
Student name and Address
LESSON
MODULE
FILE NUMBER
COURSE NAME
NAME
ADDRESS
Please verify that preprinted label is for correct course and lesson

When revised labels are received, place the correct new labels on your Lesson Record Forms.

DO NOT MARK OR COVER BAR CODING.

CHANGE OF ADDRESS

If the address on your lesson record form differs from the address you supplied on your registration application, please explain. Indicate whether the different address is your home, school, temporary or permanent change of address.

LESSON RECORD FORM

1260 Physics 10

Revised 89/02

FOR STUDENT USE ONLY

Date Lesson Submitted ______________________

Time Spent on Lesson ______________________

(If label is missing
or incorrect)

File Number ______________________

Lesson Number ____________

FOR SCHOOL USE ONLY

Assigned Teacher: ________

Lesson Grading: ______

Additional Grading E/R/P Code: ______

Mark: ________

Graded by: ________

Assignment Code: _____

Date Lesson Received: ______________

Lesson Recorded _____

Student's Questions and Comments

Apply Lesson Label Here

Name ______

Address ______

______

______

Postal Code ______

Please verify that preprinted label is for correct course and lesson.

Teacher's Comments:

____

Correspondence Teacher

St. Serv 1-86

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

AN INTRODUCTION TO PHYSICS

What Is Physics All About?

Read: "Prologue" pages viii and ix of the textbook.

Physics is a fundamental science of the natural world. It tells us what is known about the world, how what is known was found out, and how things are being found out to-day.

From times immemorial, the moon has been circling our planet. Now a man-made satellite can circle the globe for a very long time. How do satellites move? How can we design one of our own?

Physics enables us to answer such questions. It helps us to understand, to predict and to design.

Physics is the fundamental science of the natural world, but it is not the only such science. Astronomy, geology, meterology, and chemistry are some other equally important sciences. Astrophysics, geophysics and biophysics are some of the sciences bordering on physics. Astrophysics deals with the astronomical world, geophysics deals with the physics of the earth and biophysics deals with the physics of living things.

Technology is also related very closely to physics. Radio engineering, electronics and nuclear engineering are special offshoots of physics.

People who try to answer questions about the physical world while they interact with their society are called physicists. When physicists are involved primarily in designing and performing experiments, they are called experimental physicists, e.g. Benjamin Franklin and Madame Marie Curie. If they are primarily skilled in the use of mathematics in the problems of physics, they are called theoretical physicists, e.g. Isaac Newton and Albert Einstein.

In the next few lessons we will be dealing with time, space, matter, motion, and measurement. They are all related and are the basics of physics. Most of you who study the fundamentals of physics do not intend to become physicists, while some of you may go into physics or related work. Whether you go on or not, you will find that the basic study of physics helps you to understand the changing world in which we live and this can provide a deep satisfaction in your lifetime.

QUESTIONS

Match the following by placing the correct letter in the blanks provided.

I

__________ physics

__________ astrophysics

__________ geophysics

__________ offshoot of physics

__________ biophysics

__________ theoretical physicist

__________ experimental physicist

(a) the study involving the birth, death, and age of a star or the universe itself.

(b) the study of the interaction of matter and energy.

(c) deals with the effect of heat and magnetism on the rocks of the earth's crust.

(d) concerns the interaction between radiation and human tissue.

(e) radio engineering, electronics, and nuclear engineering.

(f) a physicist primarily involved in designing and performing experiments.

(g) a physicist skilled in using mathematics in the problems of physics.

II

Physics is an important study because it helps us to understand, to predict and to ____________________.

THOUGHT PROBLEM

Sometimes an investigation can be carried out, not by performing an experiment with an actual object, but by thinking about it. Most real experiments begin this way. Here is an example.

Consider throwing a ball straight up above the earth.

1. What happens to its speed during its flight?

2. Does it ever stop and if so for how long?

3. Why does it fall back down?

4. State a general rule about all objects above the earth's surface.

They tend to fall to the earth's surface unless they are adequately supported.

5. Why does the moon not fall to the earth?

The moon is constantly tending to fall to the earth (because of gravitational attraction between them) but it moves fast enough in its orbit to counteract that attraction.

6. Why does the Sun not fall to the earth?

The Perspective of the Greeks

Read: Section 1•1, pages 1-2 of the textbook.

In 335 B.C. Aristotle founded the lyceum outside the city of Athens. Alexander gave him 800 talents, an enormous grant for the time. Also he had ordered fishermen and hunters to inform Aristotle of any observed phenomena that might be of interest to him. Aristotle laid down rules of conduct, organized symposiums and research. With the death of Alexander in 323 B.C., he felt danger to his life so left Athens. A year later he died.

Aristotle wrote on subjects of natural history; he was a moralist, literary critic, physicist, biologist, political scientist, logician, teacher, and a philosopher. After Aristotle's death, his notebooks were kept in the library at Alexandria. Few original works were created in the west after the second century A.D. During the seventh and eighth century, what had been known before was largely forgotten — that is why this period is called the Dark Ages. Between the tenth and twelfth centuries, various ancient texts were rediscovered and translated. The universities of Europe started teaching Aristotle's texts. At first the newly introduced ancient writings were not accepted by the Church. In Paris, the teaching of Aristotelian physics was prohibited. Inspite of this some of the Christian scholars worked for reconciliation. Once this was achieved, an attack thereafter on Aristotle was an attack on the Church itself.

Two Types of Motion on the Earth

Read: Section 1•2, pages 3-4 of the textbook.

The earth was the center of Aristotle's universe. His universe was closely bounded by the celestial sphere. Between the celestial sphere and the earth were the spheres of all the planets, the moon, and the sun. He suggested that there were material bodies whose motions were down or up and that there were celestial bodies whose motions were in a circle about the centre of the universe. All motions were in this way divided into two classes: natural motion, motion consistent with the nature of the body, and forced or violent motion, motion not consistent with the nature of the body. Natural motion did not require any external force while forced or violent motion did require an external force. Whenever a body did not move with its natural motion, Aristotle had to find an external influence. For example, a cart, when drawn along a road, is not in its natural motion — it is the horse that provides the force. However, the stars and the moon moving around the earth require no force, since they are celestial material and are following their natural motion.

Do questions 2-4, page 4 of the textbook and check your answers given on page 147 of the textbook.

SELF CHECK

2. Explain what Aristotle meant by natural and violent motion. Give an example of each type.

3. According to Aristotle, which would hit the ground first if released from the same height, a sphere with 10 units of weight, or one with 5 units of weight? Why?

4. Answer the questions posed at the beginning of the chapter as an Aristotelian teacher might have.

1.

2.

3.

The Status of Aristotle's Teachings by the 16th Century

Read: Section 1.3, pages 4-5 of the textbook.

The details of Aristotle's physics, once they were available, were questioned by many of his Scholastic critics. Aristotle's argument for the earth's uniqueness was disputed by Nicole Oresme. He proposed that the motion of the stars cannot be deduced from the motion viewed from the earth because of those two motions being relative. Stars might be at rest while the earth moves, or the earth could be at rest while the stars move. Aristotle's theory of projectile motion came under much criticism, as it was difficult to understand why a projectile continued moving upward after the impelling force was removed.

Resistance to Change

Read: Section 1.4, pages 5-6 of the textbook.

The process of revision and criticism of the Aristotelian views gradually brought the revisors into conflict with the majority of the scholarly world, who professed to regard what they thought Aristotle had written as the last word — in fact, the only word.

But finally, as though the long years of restraint on intellectual activity, and the long years of submission to printed authority had created an unbearable pressure, the boundaries of that world of magic and animism burst. Years of criticism gradually had achieved a redefinition of the problem of the motion of bodies, which would enable a new and immensely fruitful attack on the problem of the motion of bodies.

The universe itself changed. Copernicus put the sun at the center, leaving for earth the reduced status of one among other planets. Thus, by the end of the sixteenth century, there were available alternatives to the universe as conceived by Aristotle. Rather than closed, the universe was proposed to be open; rather than filled, it was proposed to be empty.

QUESTIONS

1. Aristotle's theory of motion of the elements toward their natural place seems to be supported to a great extent by experience. Water bubbles up through the earth at springs. Fire seems to rise up and disappear as if reaching for the sky. Give some more examples of substances going toward their natural place.

2. The Aristotelian explanation of motion should not be dismissed lightly. Great intellectuals of the Renaissance period such as Leonardo da Vinci, who, among other things, designed artillery for launching projectiles, apparently did not challenge the Aristotelian explanation. One reason for the longevity of Aristotle's ideas is that they are so closely aligned with our common sense ideas. Which of the following notions support Aristotles view:

   (a) Heavy bodies fall faster towards the earth than do light ones, when falling through air. e.g. A feather falls more slowly than a penny.

   (b) A body will fall more slowly if the resistance of the meduim is greater. e.g. Through water a rock will fall more slowly than in air.

   Underline the correct response: a, b, or both.

3. By using reason alone, not by referring to any knowledge of "modern physics" that you may have, can you offer any criticisms of Greek science?

   Is qualitative observation sufficient to describe physical phenomena?

   Philosphical assumptions must correspond with experimental observations if our concepts are to be a reflection of the real world.

THE EARLY SCIENTISTS

Read: Pages 6 and 7 of the textbook and answer the following questions.

QUESTIONS

1. Complete the table for the three main periods and centers of activity in Greek science.

PERIOD (avoid names of scientists)	CENTER OF ACTIVITY
	Geometry
The Athenian	
	Astronomy and Mathematics

2. Who was the most important early Ionian scientist, and what was his significant contribution?

3. What branch of mathematics enjoyed growth under Pythagoras?

4. Did Pythagoras believe in the "thought process" or "in observations and experiments"?

5. Name six Athenians who contributed to early scientific thought.

   Socrates, Plato, Aristotle, Epicurus, Anaxagorus, Hippocrates

6. Name the two men who became known as the Atomists.

7. Give the assumptions on which the theory of the Atomists was based.

(a) ______________________________

(b) ______________________________

(c) ______________________________

(d) ______________________________

(e) ______________________________

8. Why did the ideas of the early Atomists die?

____

9. For what is Euclid known?

____

10. What was Aristarchus' field of research?

____

11. What did Aristarchus find out about the sun and the moon?

12. What was the cause of the errors in Aristarchus' findings?

13. Why is Eratosthenes' name worth mentioning among those of the early scientists?

14. What is Archimedes best-known contribution to physics?

15. What is Ptolemy's contribution to science?

16. Who was responsible for developing algebra?

EXPERIMENT # 1 FALLING OBJECTS

Read page 104 of the textbook and perform the Experiment 1.2 Falling Objects. Instead of a cylinder of water you can use a pail or a bucket and instead of marbles and steel spheres, you can use small objects of different weights, e.g. small rocks, piece of soap, marble, and a paperclip.

AIM: *To investigate the motion of several objects (of different densities) falling in water and air.*

While doing this experiment answer the questions on this page and the next.

OBSERVATION AND ANALYSIS: After making careful observations, answer the following questions.

1. How did the speed of the object behave as it fell through the water?

   The speed gradually increased.

2. What effect did the object's weight have on its rate of fall in the water?

   ____

   ____

3. What differences in the object's motion were caused by different media?

   ____

   ____

4. How do your conclusions compare with those of Aristotle?

Aristotle's conclusions	Your conclusions (agree or disagree)
a. Speed of fall is constant	
b. Objects with greater weight fall faster	
c. Thicker media slow down objects more than do thinner media	

5. Based on your conclusions for an object falling in water, what can you predict about the behaviour of objects falling in air? Underline the correct words.

Objects fall with (acceleration or constant speed) through air.
Objects fall (faster or slower) in air as compared with water.
Heavier objects fall (at same rate or faster) as compared with light objects.

6. What are the major differences between the ways in which men of modern science and of Greek science investigate nature in order to form theories? Tell whether the following are true or false.

________ The Greeks came to their conclusions about nature almost exclusively through deductive reasoning.

________ Modern science emphasizes experimentation and observations.

Scientific Notation

The term "scientific notation" is used to indicate a way of writing numbers which can simplify and shorten numerical expressions. For example, a large number such as 1 000 000 000 000 can be written as 1×10^{12}. Similarly, a small number such as 0.000 000 000 001 may be written as 1×10^{-12}. In both these cases scientific notation was used in order to write each number more quickly and in a shorter and easier-to-read form.

Scientific notation involves the use of powers of ten to express numbers. This is shown by a number of examples in the following table.

Table 1

Number	Number with power of ten		
1	1×10^0	0	These numbers are known as powers.
10	1×10^1	1	
100	1×10^2	2	
1 000	1×10^3	3	
10 000	1×10^4	·	
1 000 000	1×10^6	·	
2 500 000	2.5×10^6	·	
2 503	2.503×10^3		

Example 1

(a) If you wished to write 7 234 800 in scientific notation you could do it in the following steps:

$$\begin{aligned} 7\,234\,800 &= 7234.8 \times 1000 &&= 7234.8 \times 10^{\underline{3}} \\ &= 7.2348 \times 10^{\underline{3}} \times 1000 &&= 7.2348 \times 10^{\underline{3}} \times 10^{\underline{3}} \\ &= 7.2348 \times 10^{\underline{6}} \end{aligned}$$

(b) The decimal point was moved six places to the left,

and the power in the final answer was six.

Note that the usual way of writing large numbers in scientific notation is to have one digit to the left of the decimal point and to multiply the number by a power of ten in which the power is numerically equal to the number of places that the decimal point has been moved to the left.

Do the following exercise.

QUESTIONS

1. (a) In 721 if the decimal point is to appear between the 7 and the 2, it must be moved __2__ places to the left, and the power in the power of ten is __2__. Thus,

$$721 = 7.21 \times 10^{2}.$$

(b) In 3208 if the decimal point is to appear between the 3 and the 2, it must be moved _____ places to the left, and the power in the power of ten is _____. Thus

$$3208 = 3.208 \times 10^{—}.$$

(c) In 15 917 if the decimal point is to appear between the 1 and the 5, it must be moved _____ places to the left, and the power in the power of ten is _____. Thus,

$$15\ 917 = 1.5917 \times 10^{—}.$$

2. In the following parts of this question, indicate how many places to the left the decimal point must be moved so that it will appear between the first and second digits in the number, and complete the expression of the number in scientific notation by completing the power of ten.

(a) 231 Decimal point moved _____ places to the left.

$231 = 2.31 \times 10^{—}$

(b) 5501 Decimal point moved _____ places to the left.

$5501 = 5.501 \times 10^{—}$

(c) 93 275 Decimal point moved _____ places to the left.

$93\ 275 = 9.3275 \times 10^{—}$

(d) 815 682 Decimal point moved _____ places to the left.

$815\ 682 = 8.156\ 82 \times 10^{—}$

3. Express the following numbers in scientific notation.

(a) 153 = ______________

(b) 286 = ______________

(c) 8592 = ______________

(d) 10 158 = ______________

(e) 278 643 = ______________

(f) 8 953 295 = ______________

Small numbers can be reduced to scientific notation by several steps or by moving the decimal point several places to the right, and multiplying by a negative power of ten (such as 10^{-1}, 10^{-2}, 10^{-3}, which are the same as $\frac{1}{10}$, $\frac{1}{10^2}$, and $\frac{1}{10^3}$ respectively). See the table below.

Table II

Number in fractional form	Number in decimal form	Number in scientific notation
1	1	1×10^{0}
$\frac{1}{10}$	0.1	1×10^{-1}
$\frac{1}{100}$	0.01	1×10^{-2}
$\frac{1}{1000}$	0.001	1×10^{-3}
$\frac{1}{10\ 000}$	0.0001	1×10^{-4}
$\frac{1}{1\ 000\ 000}$	0.000 001	1×10^{-6}
$\frac{2}{1000}$	2 × 0.001	2×10^{-3}
$\frac{756}{100\ 000\ 000}$	756 × 0.000 000 01	756×10^{-8} or 7.56×10^{-6}

Please note that the negative power is numerically equal to the number of places that the decimal point is moved to the right. For example, the decimal point is moved 4 places to the right, and the power is -4 when 0.0001 is written in scientific notation.

$$\begin{aligned}
0.000\ 097\ 231 &= 0.000\ 972\ 31 \times \frac{1}{10} \\
&= 0.000\ 972\ 31 \times 10^{-1} \\
&= 0.972\ 31 \times \frac{1}{10\ 000} \\
&= 0.972\ 31 \times \frac{1}{10^{4}} \\
&= 0.972\ 31 \times 10^{-4} \\
&= \frac{9.723\ 1}{100\ 000} = \frac{9.723\ 1}{10^{5}} \\
&= 9.723\ 1 \times 10^{-5}
\end{aligned}$$

Instead of using fractions with powers of ten in the denominator, you could count the number of places the decimal point must be moved to the right so that it appears between the first and second digit (between 9 and 7). This number is equal to the negative power that should be used in the power of ten if the number is to be expressed in scientific notation.

From the above, the decimal point moved 5 places to the right and 9.723 1 is multiplied by 10^{-5} which is a negative power of ten.

Do the following exercise.

QUESTIONS

1. (a) In 0.58, if the decimal point is to appear between the 5 and the 8, it must be moved 1 place to the right. Thus, the negative power in the power of ten is -1, and $0.58 = 5.8 \times 10^{-1}$.

   (b) In 0.013, if the decimal point is to appear between the 1 and the 3, it must be moved _____ places to the right. Thus, the negative power in the power of ten is _____, and $0.013 = 1.3 \times 10^{—}$.

   (c) In 0.025 6, if the decimal point is to appear between the 2 and the 5, it must be moved _____ places to the right. Thus, the negative power in the power of ten is _____, and $0.025\ 6 = 2.56 \times 10^{—}$.

   (d) In 0.008 3, if the decimal point is to appear between the 8 and the 3, it must be moved _____ places to the right. Thus, the negative power in the power of ten is _____, and $0.008\ 3 = 8.3 \times 10^{—}$.

   (e) In 0.000 51, if the decimal point is to appear between the 5 and the 1, it must be moved _____ places to the right. Thus, the negative power in the power of ten is _____, and $0.000\ 51 = 5.1 \times 10^{—}$.

2. Complete the following table by writing the number of places the decimal point must be moved to the right if it is to appear between the first and second digit, and give the correct negative power to complete the expression of the number in scientific notation. The first one is done for you.

Number	Number of places decimal point moved to the right	Number expressed in scientific notation
0.91	1	$9.1 \times 10^{\underline{-1}}$
0.163		1.63×10^{___}
0.095		9.5×10^{___}
0.008 11		8.11×10^{___}
0.000 78		7.8×10^{___}
0.000 056		5.6×10^{___}

Review of the Rules of Multiplication and Division with Powers

As you should know from your mathematics courses, there are certain rules which must be followed when multiplying or dividing numbers which are expressed using powers. These rules are listed below. Please study them carefully.

1. Two (or more) powers must have the same base before the powers can be directly combined (according to Rules 2 and 3 below) in multiplication or division.

   The base of such powers as 10^2, 10^3, 10^{-6}, 10^{-18} is 10.

   Similarly, the base of such powers as 2^2, 2^5, 2^{-10}, 2^{-3} is 2.

2. When multiplying two (or more) powers of the same base, the powers are added.

   For example, $10^2 \times 10^3 = 10^{2+3} = 10^5$. This can be shown to be true by the following:

$$
\begin{aligned}
10^2 &= 10 \times 10 \\
10^3 &= 10 \times 10 \times 10 \\
10^2 \times 10^3 &= (10 \times 10) \times (10 \times 10 \times 10) \\
&= 10 \times 10 \times 10 \times 10 \times 10 \\
&= 10^5
\end{aligned}
$$

Other examples:

$$10^{3} \times 10^{9} \times 10^{2} = 10^{3+9+2} = 10^{14}$$

$$10^{-5} \times 10^{-6} = 10^{-5+(-6)} = 10^{-5-6}$$
$$= 10^{-11}$$

$$10^{-4} \times 10^{8} = 10^{-4+8}$$
$$= 10^{4}$$

3. When dividing two (or more) powers of the same base, the powers are subtracted.

Examples:

$$\frac{10^{5}}{10^{4}} = 10^{5-4} = 10^{1} = 10$$

$$\frac{10^{8}}{10^{8}} = 10^{8-8} = 10^{0} = 1$$

$$\frac{10^{2}}{10^{12}} = 10^{2-12} = 10^{-10}$$

$$\frac{10^{5}}{10^{-6}} = 10^{5-(-6)} = 10^{5+6} = 10^{11}$$

Note that $10^{1} = 10$, and that $10^{0} = 1$. Sometimes when powers are combined, the resulting power will be zero. Any base number raised to a power of 0 equals 1.

Note that when a power is moved from the denominator to the numerator, or vice versa, in a fraction, the sign of the exponent changes.

For example,

$$\frac{1}{10^{2}} = 1 \times 10^{-2}$$

$$10^{3} = 1 \times 10^{3} = \frac{1}{10^{-3}}$$

$$\frac{10^{7}}{10^{9}} = 10^{7} \times \frac{1}{10^{9}} = 10^{7} \times 10^{-9} = 10^{-2}$$

To further show this, consider again the fraction $\frac{1}{10^{2}}$. We have $10^{2} = 100$, so that $\frac{1}{10^{2}} = \frac{1}{100}$. If we complete the division of 100 into 1, we obtain $\frac{1}{100} = 0.01$. Remembering the rule for conversion to scientific notation, in 0.01 the decimal point must be moved two places to the right. This gives a power of -2, and $0.01 = 1 \times 10^{-2}$. Therefore, we have $\frac{1}{10^2} = 1 \times 10^{-2}$.

Do the following questions.

QUESTIONS

1. Can the product (or quotient) of the two numbers 2^5 and 3^7 be found simply by directly combining the powers? Explain your answer.

____

____

2. Find the products of the following numbers by combining the powers.

(a) $2^5 \times 2^2$ = ________ (d) $10^{-1} \times 10^5$ = ________

(b) $3^8 \times 3^2$ = ________ (e) $10^9 \times 10^3$ = ________

(c) $7^6 \times 7^7$ = ________ (f) $10^{\frac{1}{2}} \times 10$ = ________

3. Find the quotients of the following numbers by combining the powers.

(a) $\frac{2^5}{2^2}$ = (d) $\frac{10^{-1}}{10^5}$ =

(b) $\frac{3^8}{3^2}$ = (e) $\frac{10^9}{10^3}$ =

(c) $\frac{7^6}{7^7}$ = (f) $\frac{10^{\frac{1}{2}}}{10}$ =

4. Move the numbers in the denominators of the following fractions to the numerators, and make the appropriate change in the sign of the powers so that the numbers will be equal.

(a) $\frac{1}{10^5}$ = ________ (d) $\frac{2}{10^2}$ = ________

(b) $\frac{1}{10^{-8}}$ = ________ (e) $\frac{5}{10^{-11}}$ = ________

(c) $\frac{1}{2^3}$ = ________ (f) $\frac{3}{10^{80}}$ = ________

Multiplying and Dividing Numbers in Scientific Notation

You may have to multiply and divide numbers which are in scientific notation often when you do physics problems. You can do this fairly easily by using what you know concerning multiplication or division of powers by direct combination of powers. A method of doing such computations is outlined below.

Steps to Complete	Sample Computation
1. Multiply or divide all the powers of ten so that a single power of ten results.	$2.0 \times 10^5 \times 6.0 \times 10^2$ $= 2.0 \times 6.0 \times 10^5 \times 10^2$ $= 2.0 \times 6.0 \times 10^7$
2. Multiply or divide the other numbers (the factors of the powers of ten) so that one number results.	$2.0 \times 6.0 \times 10^7$ $= 12 \times 10^7$
3. If necessary, put the number resulting from multiplying or dividing the factors of the powers of ten in scientific notation.	12×10^7 $= (1.2 \times 10^1) \times 10^7$
4. If necessary, combine the two powers of ten to obtain a single number in scientific notation.	$1.2 \times 10^1 \times 10^7$ $= 1.2 \times 10^8$

Do the following questions.

QUESTIONS (Express all answers in scientific notation)

1. Find the products of the numbers indicated in the following parts of this question.

   (a) $2 \times 10^2 \times 1 \times 10^5 =$ ____________________

   (b) $7 \times 10^8 \times 2 \times 10^2 =$ ____________________

   (c) $2.5 \times 10^6 \times 4.0 \times 10^3 =$ ____________________

   (d) $9.0 \times 10^6 \times 9.0 \times 10^{12} =$ ____________________

2. Find the quotients of the numbers indicated in the following parts.

(a) $10^5 \div (5 \times 10^3) =$ ______________________________

(b) $(9 \times 10^2) \div (3 \times 10^8) =$ ______________________________

(c) $(1.6 \times 10^9) \div (4.0 \times 10^9) =$ ______________________________

(d) $(2.56 \times 10^{17}) \div (1.6 \times 10^{-17}) =$ ______________________________

3. Complete the computation indicated below, and give the answer as a single number in scientific notation.

$$\frac{3.00 \times 10^5 \times 6.00 \times 10^{-1} \times 3.00 \times 10^{-2} \times 2.00 \times 10^2}{2.00 \times 10^{-8} \times 6.00 \times 10^{10}}$$

A Personal Guide for Lesson Completion in Your Correspondence Course

Below you will find a procedure for calculating the frequency with which you must submit lessons in your correspondence course to finish by the date you have chosen. Use it as a guide in working on your lessons and try to follow it as closely as possible. If you do, your lessons will not stack up at the end, either for you or for the teachers at the Alberta Correspondence School.

Study the example given below and complete pages 23 and 24 accordingly.

Example: Suppose it is October 20, you have 12 lessons to do and you wish to finish by January 6.

$$\text{No. of days remaining} = \overset{\text{Oct.}}{(31 - 20)} + \overset{\text{Nov.}}{30} + \overset{\text{Dec.}}{31} + \overset{\text{Jan.}}{6} = 78 \text{ days}$$

$$\frac{\text{No. of days}}{\text{No. of lessons remaining}} = \frac{78 \text{ days}}{12 \text{ lessons}} = 6.5 \, \frac{\text{days}}{\text{lesson}}$$

You have approximately 6 days to do each lesson.

Lesson	To Be Completed By
Today's date	October 20
1	October 26 (add 6 to 20)
2	November 1 (add 6 to 26)
3	November 7
etc.	etc.
12	December 31

Note that since you rounded off 6.5 days to 6 days you will be finishing early. But this is much better than finishing too late by using $7 \, \frac{\text{days}}{\text{lesson}}$.

Pages 23 and 24 MUST be submitted with this lesson so that your teacher will know how you plan to schedule the work on your course. They will be returned to you with the lesson so that you can keep them handy as a guide.

1. By what date do you wish to finish the course? ____________________

(NOTE: In order to write a final examination in the first semester, you are advised to have all lessons at the Alberta Correspondence School by January 7th of the same school year.

In order to write the examination in the second semester, you are advised to have all lessons at the Alberta Correspondence School by June 1 of the same school year.

2. Today's date is ____________________.
Now count the number of days on the calendar between now and the day you want to finish.

Calculations:

September =
October =
November =
December =
January =
February =
March =
April =
May =

How many days are there? ____________________.

3. Now divide the number of days between now and the finishing date by the number of lessons you have left to do.

$$\frac{\text{No. of days}}{\text{No. of lessons remaining}} = \frac{\_\_\_\_\_\_\_\_\ \text{days}}{\text{lessons}} = \underline{\qquad\qquad}\ \frac{\text{days}}{\text{lesson}}$$

The last figure you have calculated is the number of days you have on the average to complete each lesson. (For example, if the number is 5.7 $\frac{\text{days}}{\text{lesson}}$ you have approximately 5 days to work on each lesson).

4. Using this number fill in the following chart.

	To Be Completed By
Lesson 1	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	
Lesson	

NOTE: Students who have chosen the elective Motion in the Heavens would be well advised to complete Lessons 10A, 11A and 12A before going on with Lessons 2 to 9 if starting the course at the beginning of a school semester. September-October and January-February are ideal times for making astronomical observations.

Note: Calculators are allowed in the course and on the final test.

End of Lesson 1

NOTE: The elective selection forms and the questionnaire on the following pages MUST be completed and submitted with this lesson.

Physics 10 Elective Selection Form

Student Copy

Please complete this form, and keep it with you so that you can keep a record of your elective selection.

Name ____

Address ____

____

File # ____________

Students taking the Physics 10 course must select one of the electives listed below by placing a check mark in the box to the right of the selection. Before making your selection, see the descriptions of the electives.

Physics 10 Elective A Motion in the Heavens I ☐

Physics 10 Elective B Fluids at Rest ☐

Descriptions of Electives

Elective A Motion in the Heavens - This elective involves a beginning study of astronomy with an emphasis on how we have come to understand the various motions of heavenly bodies, like those of the sun, the moon and the planets. It includes simple naked eye observations that will help you become familiar with some of the brighter stars and constellations. If you expect that you may not be able to make observations of the night sky, you should not select this elective.

Elective B Fluids at Rest - This elective involves a study of pressure and density of fluids at rest; buoyancy and Archimedes' Principle; Pascal's Principle and the basics of hydraulic machines. No special equipment for experiments is required.

Physics 10 Elective Selection Form

Alberta Correspondence School Copy

Please complete this form, and send it in with your first lesson.

Name ______________________________

Address ______________________________

____

File # ______________

Students taking the Physics 10 course must select one of the electives listed below by placing a check mark in the box to the right of the selection. Before making your selection, see the descriptions of the electives.

Physics 10 Elective A Motion in the Heavens I ☐

Physics 10 Elective B Fluids at Rest ☐

Descriptions of Electives

Elective A Motion in the Heavens - This elective involves a beginning study of astronomy with an emphasis on how we have come to understand the various motions of heavenly bodies, like those of the sun, the moon and the planets. It includes simple naked eye observations that will help you become familiar with some of the brighter stars and constellations. If you expect that you may not be able to make observations of the night sky, you should not select this elective.

Elective B Fluids at Rest - This elective involves a study of pressure and density of fluids at rest; buoyancy and Archimedes' Principle; Pascal's Principle and the basics of hydraulic machines. No special equipment for experiments is required.

COMPLETE THIS FORM AND RETURN WITH LESSON ONE

Physics 10

Name ______________________________ Age
File Number

Address ______________________________ Phone Number

______________________________ Postal Code

1. Name of present school (if in attendance) ______________________________

2. Give your final mark (if any) in the following subjects:

Science 9 ______
Mathematics 9 __
Chemistry 10 ___
Chemistry 20 ___
Chemistry 30 ___
Mathematics 10 ___
Mathematics 20 ___
Mathematics 30 ___
Biology 10 _____
Biology 20 _____
Biology 30 _____
Physics 10 _____

3. Do you plan to purchase a laboratory kit? ______________________________

4. List any special qualifications or handicaps (jobs, illness, disabilities, etc.) which may influence your progress in this course. ______________________________

5. What is your reason for enrolling in this course? ______________________________

6. List any other subjects you are studying by correspondence instruction. ______________________________

Lesson	In	Out	Grade	
1				
2				
3				
4				
5				
6				
7				
8				
9				
1A, 1B				
2A, 2B				
3A, 3B				
EXAM				

Lesson Grade

Exam Portion
Lesson Portion
Final Grade

LESSON RECORD FORM

1260 Physics 10

Revised 89/02

FOR STUDENT USE ONLY

Date Lesson Submitted ______________________

Time Spent on Lesson ______________________

(If label is missing
or incorrect)

File Number ______________________

Lesson Number ____________

FOR SCHOOL USE ONLY

Assigned
Teacher: ________

Lesson Grading: ______

Additional Grading
E/R/P Code: ______

Mark: ____________

Graded by: __________

Assignment Code: _____

Date Lesson Received:

____

Lesson Recorded _____

**Student's Questions
and Comments**

Apply Lesson Label Here

Name

Address

Postal Code

*Please verify that preprinted label is for
correct course and lesson.*

Teacher's Comments:

____

Correspondence Teacher

St. Serv. 1-86

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

MOTION AND MEASUREMENT

In this lesson you will learn about the connections between speeds, positions and times. The subject of such relationships is called kinematics. Since motion is the change of distance as the time elapses, so we shall deal with the measurement of time and distance. In a measurement you will be interested in the accuracy of the measurement.

Accuracy of Measurement

Significant digits express the degree of accuracy of measurements e.g. the length of a table is measured to the nearest cm and is found to be 1.52 m. It contains three significant digits accuracy. If the measurement were done so that it was accurate only to the nearest 0.1 m it would be recorded as 1.5 m with only 2 significant digits.

Significant Digits

Definition

The number of places to the left and right of the decimal point in a number, beginning with the first nonzero digit and ending with the last validly retained digit, is called the number of significant digits (S.D.). Thus

1. All the digits from 1 to 9 including any zeros between them or after the decimal are significant digits.

2. The zeros preceding the first digit are not significant, but zeros after the first digit will be considered significant digits. Therefore,

$\underline{7.231}$ has 4 S.D.
$0.0\underline{12}$ has 2 S.D.
$\underline{2.30}$ has 3 S.D.
$\underline{2.700}$ has 4 S.D.
$0.0\underline{140}$ has 3 S.D.
7.0 has 2 S.D.
8.00 has 3 S.D.

Some numbers are exactly correct. For example, the number of players in a team, number of employees in an office or by definition, 1 yard is 0.9144 m exactly. The number of significant digits in such cases is infinite.

It is preferable, in expressing final answers such as 4700 units, to write either 4.7×10^3 units, 4.70×10^3 units, or 4.700×10^3 units to indicate appropriate number of significant digits. Notice that the ambiguity regarding the number of significant digits is removed.

Multiplication and Division

The number of significant digits of a product or quotient is not greater than the number of such digits in either factor e.g.

The answer to 14.75 x 15.2 should not have more than 3 S.D.

The answer to 16.35 ÷ 2.3 should not have more than 2 S.D.

The answer to $5.3151 \times 10^5 \div 1.1 \times 10^4$ should not have more than 2 S.D.

Do the required multiplication or division with all of the digits available, then round down to the appropriate number of significant digits. If the digit you drop is 5 or greater, add one to the preceding number. So 43.45 becomes 43.5 to 3 S.D.

PROBLEMS

Perform the operation indicated and round off your answer to the proper number of significant digits. Express in scientific notation.

1. $4.12 \times 0.24 = 0.9888 = 9.888 \times 10^{-1}$
$= 9.9 \times 10^{-1}$ (rounded to 2 S.D.)

2. $0.015 \times 346 \times 5142 =$
=

3. $5.3 \times 10^2 \times 6.77 \times 10^3 =$
=

4. $6.45 \times 10^6 \div 0.007 =$
=

Addition or Subtraction

When you are adding or subtraction, however, you handle the significant digits not on the basis of how many there are altogether, but how many there are after the decimal.

Rule: In operations involving addition and subtraction of numbers of which the least precise (least number of decimals) has N places of decimals, do the required operations and round off the final answer to N places of decimals.

For example,

6.7981; 0.2966; 1.008; 0.03 are to be added.

$$6.781 + 0.2966 + 1.008 + 0.03 = 8.1327$$

Now round off the final answer to 2 places of decimal i.e. 8.13.

PROBLEMS

Perform the operations indicated and round off your answer to the proper number of significant digits.

1. $68.95 + 5.8 = 74.75$

   $= 74.8$

2. $53.521 + 63.13 =$

   $=$

3. $6.9834 - 0.03 =$

   $=$

4. $6.54 \times 10^4 - 3.1 \times 10^4 =$

   $=$

5. $93.27 + 6.543 =$

   $=$

SI (The Latest Version of the Metric System)

The Change to Metric: Through the centuries, many measurement systems have developed, evolving from numerous origins, convenient customs, and local adaptations. Most systems have lacked rational structure. The Imperial system — using the yard, quart, and pound — is one such conglomeration of poorly related units.

About 200 years ago, France decided to bring order out of her chaotic measures and the metric system was born. Although strongly opposed at first, this new system proved effective and gained popularity, so much so, that over 90% of the world's population now lives in countries that have adopted or are changing to the metric system.

Various Versions of Metric Systems: There have been several metric systems, but each new version has added more metric units, causing unnecessary congestion. To make matters worse, in some applications there has been a mixture of both Imperial and metric units, and something had to be done to clean house.

The Latest Version of the Metric System: In 1960 the International System of Units was established as a result of a long series of international discussions. This modernized metric system, called SI, from the French name, Le Systeme International d'Unites, is now, as a general world trend, to replace all former systems of measurement, including former versions of the metric system. Canada has decided to convert to SI.

Many European nations are making the change to SI — a change from former metric practice. The United Kingdom, Australia, New Zealand, South Africa, and others are adopting SI, while countries such as India, China, and Japan are updating their metric practice to conform to SI. In the United States, major industries are tooling up for metric conversion, and their choice, too, is SI.

It's SI, not S.I. — omit the periods.

It's just called SI not the "SI system", since the "S" stands for the word "system".

SI is Similar but Different: SI includes familiar metric units such as the metre and kilogram. There are, however, a number of changes from former metric systems. For instance, the centigrade temperature scale is called the Celsius (pronounced sell-see-us) scale when used for general purposes. This is a change in name only, so that 20°C, formerly read as "twenty degrees centigrade", is now read as "twenty degrees Celsius." There is no change in the scale, only in the name. Water still freezes at 0°C and boils at 100°C (degrees Celsius, that is). This kind of change is not difficult for those who are familiar with older metric systems.

Numbers moulded metrics: The metric system was based on the convenience of the decimal number system. Units are related by factors such as 10, 100, and 1000. This makes computation in the metric system much simpler than that with Imperial measures. A great deal of the arithmetic merely involves the shifting of the decimal, without tedious calculations.

This course is written using SI units exclusively. The table of units on the following pages is a reference guide so you can easily understand what these units mean. Please: Try to think metric and use metric measures wherever possible.

TABLE OF SI UNITS AND NON-SI UNITS PERMITTED FOR USE WITH SI

The table is put in the order of most probable frequency of use. So units that would be used frequently are put first, and units less frequently toward the last. The conversion factors are to be used ONLY IF you are reading a book or shop manual that has Imperial units. It is recommended that the student start thinking entirely metric, and not even think about the Imperial units at all! The student should use metric measurements in his daily life exclusively so it becomes a matter of habit. Be modern and up to date! Use SI, and insist that your friends use it too!

Table of Prefixes

Prefix	Symbol	Meaning	Multiplier	
tera	T	one trillion	1 000 000 000 000	$= 10^{12}$
giga	G	one billion	1 000 000 000	$= 10^{9}$
*mega	M	one million	1 000 000	$= 10^{6}$
*kilo	k	one thousand	1 000	$= 10^{3}$
hecto	h	one hundred	100	$= 10^{2}$
deca	da	ten	10	$= 10^{1}$
*		one	1	$= 10^{0}$
deci	d	one tenth of a	0.1	$= 10^{-1}$
*centi	c	one hundredth of a	0.01	$= 10^{-2}$
*milli	m	one thousandth of a	0.001	$= 10^{-3}$
micro	μ	one millionth of a	0.000 001	$= 10^{-6}$
nano	n	one billionth of a	0.000 000 001	$= 10^{-9}$
pico	p	one trillionth of a	0.000 000 000 001	$= 10^{-12}$
femto	f	one quadrillionth of a	0.000 000 000 000 001	$= 10^{-15}$
atto	a	one quintillionth of a	0.000 000 000 000 000 001	$= 10^{-18}$

* - most commonly used

Unit	Symbol	Meaning	Example
terametre	Tm	10^{12} m	Distance from sun to Saturn = 1.4 Tm.
gigametre	Gm	10^{9} m	About 3 times distance from earth to moon.
megametre	Mm	10^{6} m	Distance from Calgary to northern Alberta border.
kilometre	km	10^{3} m	Length of brisk 10 min walk.
metre	m	1 m	Height of 3-drawer filing cabinet.
millimetre	mm	10^{-3} m	Thickness of a dime.
micrometre	μm	10^{-6} m	Size of bacteria.
nanometre	nm	10^{-9} m	Length of oil molecule.
picometre	pm	10^{-12} m	Wavelength of gamma rays.
femtometre	fm	10^{-15} m	Diameter of a proton.
attometre	am	10^{-18} m	???

QUANTITY	NAME	SYMBOL	NOTES	CONVERSION
length	millimetre	mm		1 inch = 25.4 mm
	centimetre	cm		1 foot = 30.48 cm
	metre	m	A Volkswagen is about 4 m long.	1 yard = 0.9144 m
	kilometre	km		1 mile = 1.609 344 km
area	square centimetre	cm^2		1 square inch = 6.451 6 cm^2
	square metre	m^2		
volume	cubic centimetre	cm^3	1 cm by 1 cm by 1 cm	
	cubic metre	m^3		
	millilitre	mL	There are 1 000 mL in 1 L.	
	litre	L	1 L is the volume of a cube 10 cm by 10 cm by 10 cm.	1 gallon = 4.546 L
mass	gram	g		1 ounce = 28.349 523 g
	kilogram	kg		
	milligram	mg		
	tonne	t	1 t is 1 000 kg, this is about the mass of a Volkswagen.	
temperature	degree Celsius	°C	A comfortable room has a temperature of 20°C	$°C = \frac{5}{9}(°F - 32)$
time	hour	h		
	minute	min		
	second	s		
numeric dating	In SI dates are expressed in this exact order: YEAR-MONTH-DAY. The month is not written out. EXAMPLE: 1977-10-31 is October 31, 1977			

QUANTITY	NAME	SYMBOL	NOTES	CONVERSION
speed	kilometre per hour	km/h	A good highway cruising speed would be 100 km/h	1 mile per hour = 1.609 344 km/h
	metres per second	m/s		
	metres per hour	m/h		
acceleration	metres per second squared	m/s^2		
gasoline consumption	litres per one hundred kilometres	L/100 km	We are likely to express gas consumption by cars in litres per hundred kilometres, that is, the amount of gasoline it takes for the car to travel 100 km. For instance, a large car may consume gas at 20 L/100 km, while a smaller car may only require about 8 L/100 km. The lower the number of litres, the less gas you consume. This way of stating fuel consumption is prevalent in Europe and other metric areas of the world.	
pressure	pascal	Pa		
	kilopascal	kPa	The atmospheric pressure is about 100 kPa.	1 psi = 6.894 757 kPa
power	watt	W		1 horsepower = 745.699 9 W
	kilowatt	kW	A lawnmower has a power of about 2 kW.	
force	newton	N	The newton is roughly the force required by your hand when supporting 2 golf balls.	1 pound = 4.448 222 N
electric current	ampere	A		
electric potential, potential difference, electromotive force	volt	V		

QUANTITY	NAME	SYMBOL	NOTES	CONVERSION
resistance	ohm	Ω		
rotational frequency	revolutions per minute	min^{-1}	An LP record has a rotational frequency of 33 min^{-1}.	
energy, work	joule	J		1 Btu = 1 055.06 J 1 calorie = 4.186 8 J
moment of force, torque	newton metre	N·m		
density	kilograms per cubic metre	kg/m^3		
relative density	The terms "specific weight" and "specific gravity" should be replaced by the term "relative density". Mercury has a relative density of 13.6, meaning that it is 13.6 times as dense as water. Water is implied as the reference substance for liquids and solids, and air the reference for gases, unless indicated otherwise.			
capacitance	microfarad farad	µF F		
electric charge	coulomb	C	One coulomb is the charge transported in 1 s by a current of 1 A.	
electric flux	coulomb	C		
magnetic field strength	ampere per metre	A/m		
wave frequency	hertz	Hz	This unit replaces the cycle per second (cps).	1 Hz = 1 cps OR 1 Hz = s^{-1}

RULES FOR WRITING SI

1. The symbols are always printed in Roman (upright) type, irrespective of the type face used in the rest of the text.

2. Symbols are never pluralized: 45 g (not 45 gs)

3. Never use a period after a symbol, except when the symbol occurs at the end of a sentence. This is done because SI symbols are SYMBOLS they are NOT abbreviations.

   Example: the symbol for kilogram is kg NOT kg.

4. Symbols should usually be used and unit names should not be mixed with symbols.

   Example: 10 kg (preferred), ten kilograms (accepted), never 10 kilograms

5. Always use a full space between the quantity and the symbol: 45 g (not 45g)

   Exception: For Celsius temperatures the degree sign occupies the space. 32°C (not 32° C or 32 °C)

6. Use decimals, not fractions: 0.25 g (not 1/4 g)

7. A zero is always used before a decimal marker for less than one unit: 0.45 g (not .45 g)

8. Symbols are written in lower case, except when the unit is derived from a proper name:

   m for metre; s for second; but N for newton; A for ampere; degree Celsius °C is the only one to be upper case in both name and symbol.

   Exception: The symbol for litre is L

9. Prefixes are printed in Roman (upright) type without spacing between the prefix and the unit symbol: kg for kilogram, km for kilometre

   Only one prefix is applied at one time to a given unit: megagram
   or tonne,
   NOT kilokilogram

10. Use spaces to separate long lines of digits into easily readable blocks of three digits with respect to the decimal marker: 32 453.246 072 5

    Exception: A space is optional with a four-digit number: 1 234 or 1234

11. Multiplication of units in symbolic form is indicated by a dot at mid-letter height between the symbols.

12. Division of units in symbolic form is indicated by an oblique stroke between the symbols, or by a negative exponent. Note that the double oblique stroke is not allowed without the use of brackets. Use m/s^2 or (m/s)/s NOT m/s/s for the units of acceleration.

EXAMPLE 1 Convert the following quantities as required.

(a) 0.45 m = cm (b) 0.32 kg = g

(c) 3×10^8 m/s = km/s (d) 1×10^8 μF = F

Solution:

(a) 0.45 m = cm

Since metre is to be converted into cm, you have to know the relationship between the two i.e. 1 m = 100 cm

$$0.45\text{ m} \times \frac{100\text{ cm}}{1\text{ m}} = 45\text{ cm}$$

$$0.45\text{ m} = 45\text{ cm}$$

(Note that the ratio $\frac{100\text{ cm}}{1\text{ m}} = 1$, and therefore it does not change the value of the quantity.)

(b) 0.32 kg = g

Because 1 kg = 1000 g

Therefore, $0.32\text{ kg} \times \frac{1000\text{ g}}{1\text{ kg}} = 320\text{ g}$

or $0.32\text{ kg} = 320\text{ g} = 3.2 \times 10^2\text{ g}$

(c) 3×10^8 m/s = km/s

Because 1 km = 1000 m

Therefore, $3 \times 10^8\ \frac{\text{m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} = 3 \times 10^5\text{ km/s}$

or $3 \times 10^8\text{ m/s} = 3 \times 10^5\text{ km/s}$

(d) 1×10^8 μF = F

Because $1\ \mu\text{F} = 10^{-6}\text{ F}$

Therefore, $1 \times 10^8\ \mu\text{F} \times \frac{10^{-6}\text{ F}}{1\ \mu\text{F}} = 1 \times 10^2\text{ F}$

or $1 \times 10^8\ \mu\text{F} = 1 \times 10^2\text{ F}$

EXAMPLE 2: Convert 30 km/h into m/s.

Solution: You have to convert km into m and h into s. You know that

1 km = 1000 m and 1 h = 3600 s

Therefore, $\frac{30\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{\text{km}} \times \frac{1\text{ h}}{3600\text{ s}} = 8.3\text{ m/s}$

PROBLEMS

Convert the following quantities as required.

1. $0.50\ \text{m} = 0.50 \times 10^2\ \text{cm}$
$= 5.0 \times 10^1\ \text{cm}$

2. 0.35 kg = g
= g

3. 1500 m = km
= km

4. 100 mL = L
= L

5. $1\ 000\ 000\ 000\ \Omega = 1 \times 10^3\ \text{M}\Omega \qquad 1 \times 10^9\ \Omega \times \frac{1\text{M}\Omega}{1 \times 10^6\ \Omega}$
$= 1000\ \text{M}\Omega$

6. 0.000 000 001 F = μF
= μF

7. $4500\ \text{mm} = 450\ \text{cm} \qquad 4500\ \text{mm} \times \frac{1\ \text{cm}}{10\ \text{mm}} = 450\ \text{cm}$
$= 4.50\ \text{m} \qquad 450\ \text{cm} \times \frac{\text{m}}{100\ \text{cm}} = 4.50\ \text{m}$

8. $1.0\ \text{m}^3 = \quad \text{cm}^3$

9. 36 km/h = m/s

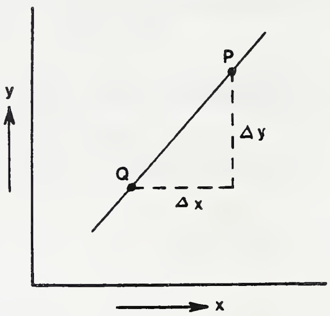
Slope of a Line

In common usage the word slope refers to the position of other than horizontal surfaces. For example, a house builder may describe the slope of stairs in terms of a vertical rise in a horizontal distance while a skier may refer to the side of a hill. Here we will describe the special meaning of slope in mathematics and physics. It is quite close to the common meaning but is more precise.

Suppose P and Q are two points in a plane as shown in Fig. A. The increment in y in going from Q to P is called the rise (Δy) and the increment in x from Q to P is called the run (Δx). (Read Δy, delta y and Δx, delta x).

$$\text{slope} = \frac{\Delta y}{\Delta x}$$

Fig. A



The slope of a straight line is the same as the slope of any segment of the line.

If the line is horizontal the slope is zero.

If the line is vertical the slope is undefined.

If the line rises to the right the slope is positive.

If the line falls to the right the slope is negative.

Uniform Motion

Read sections 2.2 and 2.3, pages 10-14 of the textbook.

Uniform motion is motion at a constant speed in a straight line. For a body moving with a uniform motion, the definition for speed is

$$\text{speed} = \frac{\text{distance travelled}}{\text{time interval}}$$

Writing symbolically, it is

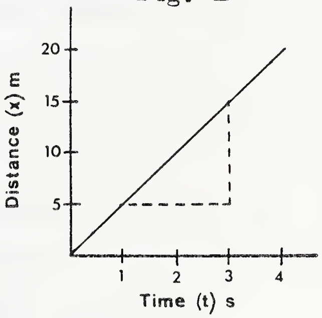
$$v = \frac{\Delta x}{\Delta t}$$

Where Δx is the distance travelled and Δt is the time interval. The units of speed will then be m/s or km/h etc.

Both equations and graphs are useful methods of describing motion. Graphs are preferred sometimes because graphs let us visualize what is happening.

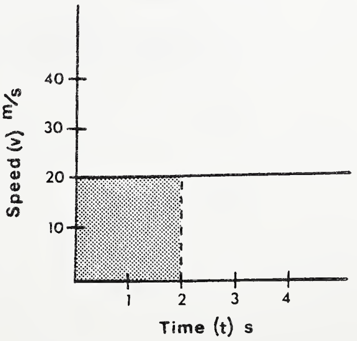
A Distance-Time graph for uniform motion is a straight line and the slope of the line equals the speed. e.g. $\frac{(15 - 5)\text{ m}}{(3 - 1)\text{ s}} = 5\text{ m/s}$ is the speed of the body represented in Fig. B.

Fig. B



A Speed-Time graph for uniform motion is a straight horizontal line. The intercept on the speed axis equals the speed. The area under the line for a certain time-interval equals the distance travelled during the time-interval. In Fig. C, the speed of the object is 20 m/s and the distance travelled in 2 s is the shaded area i.e. 20 m/s × 2 s = 40 m.

Fig. C



SELF CHECK

Do questions 1-4, page 15 of your textbook and check your answers with the answers given on page 147 of the textbook. You do not have to send the self-check questions for corrections.

1. State three different units that could be used to measure speed.

2. From among the examples below indicate those that illustrate uniform motion.

   (a) A billiard ball rolls on a flat table.
   (b) A ball is dropped out of a window.
   (c) An elevator travels upward in a very high building.
   (d) A football is thrown in air and caught 30 m away.
   (e) The sound of a shotgun blast travels across a field.
   (f) A sky diver falls freely for several hundred metres before pulling his ripcord.

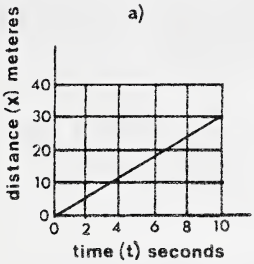
3. Use the problems in the chart below to review the equations.

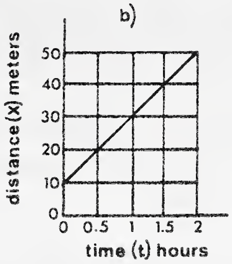
	SITUATION	FIND
(a)	Speed uniform, distance travelled = 72 cm time elapsed = 12 s	Speed
(b)	Speed uniform at 45 km/h	Distance travelled in 20 min
(c)	$x_1 = 0$ $t_1 = 0$ $x_2 = 15$ cm $t_2 = 5.0$ s $x_3 = 30$ cm $t_3 = 10$ s	Speed and distance travelled at 8.0 s

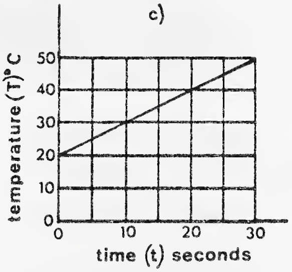
(a) (c)

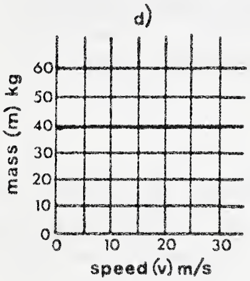
(b)

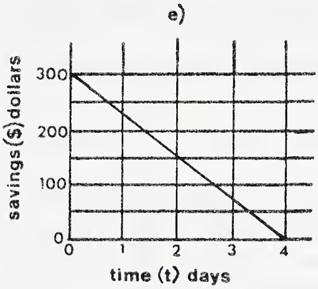
4. Determine the values for the slopes of the lines in each of the graphs below.

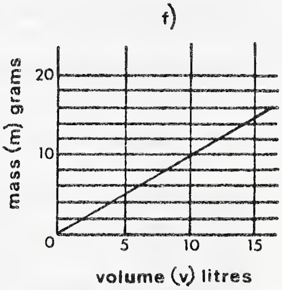












(a)

(b)

(c)

(d)

(e)

(f)

Lesson Summary

Much of the ambiguity about significant digits can be removed by writing the number in scientific notation. Therefore it is always advisable to write your answer in scientific notation.

Uniform motion is motion at a constant speed in a straight line.

Speed is defined as, $v = \frac{\Delta x}{\Delta t}$,

where Δx is the distance travelled and Δt is the time-interval.

Distance-Time graph for uniform motion is a straight line.

The slope of the line equals the speed.

Speed-Time graph for uniform motion is a straight horizontal line. The intercept on the speed axis equals the speed. The area under the line for a certain time-interval equals the distance travelled during the time-interval.

PROBLEMS

1. Draw on the graph paper provided the distance-time graphs representing objects travelling in uniform motion at 5 m/s, 20 m/s and 30 m/s. Draw the three lines on the same set of axes. Label the axes and title the graph.

   If you complete the tables below for the three cases, it will make your task easier.

Table 1: For 5 m/s

Time	Distance
0	0
1	
2	
3	
4	
5	
6	
7	35
8	
9	

Table 2: For 20 m/s

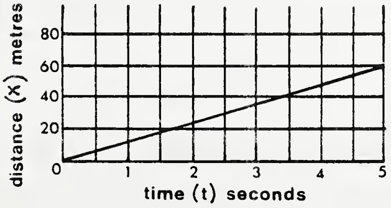
Time	Distance
0	
1	20
2	
3	
4	
5	
6	
7	140
8	
9	

Table 3: For 30 m/s

Time	Distance
0	
1	
2	
3	
4	
5	
6	
7	210
8	
9	

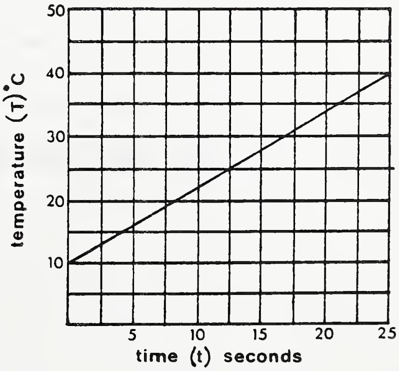
2. Determine the values for the slopes of the lines in each of the graphs below.

Fig. D



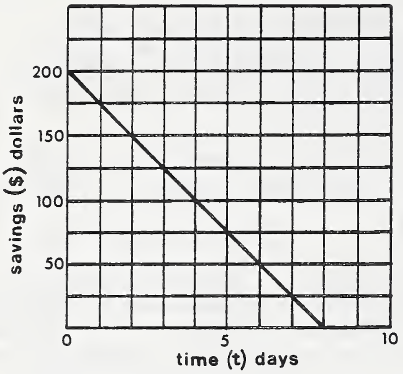
Slope = ______________

Fig. E



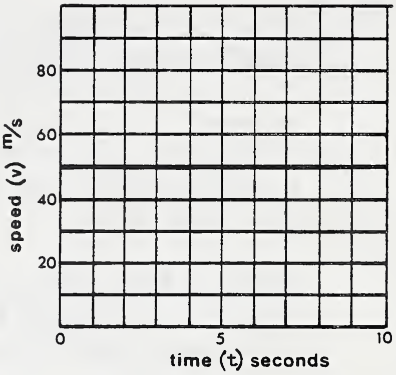
Slope = ______________

Fig. F



Slope = ______________

Fig. G



Slope = ______________

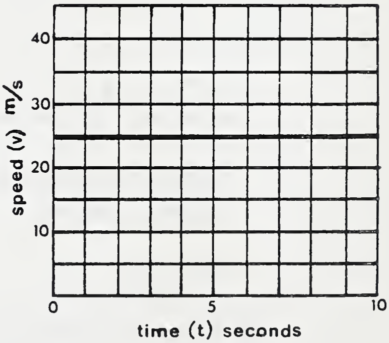
3. (a) Describe the motion illustrated by the speed-time graph shown in Fig. H.

____

____

____

Fig. H



(b) What graphical feature is considered when this graph is used to determine the distance travelled?

____

____

(c) Use this feature to show the distance travelled in 8 s.

4. A body travelling with a uniform speed covers 5.1×10^2 m in 0.30 h. Find the speed of the body in km/h.

5. A body covers 25 cm in 5.0 s and 65 cm in 13 s. What will be the distance travelled in 25 s?

6. The distance from Calgary to Edmonton is 290 km. How long will a safe driver take to travel this distance at a uniform speed of 90 km/h?

EXPERIMENT #2

Design an experiment to measure the average speed of you walking. Try the experiment and report your procedure and results. (Remember that average speed equals total distance travelled divided by the time it takes to travel that distance.)

AIM: *To find your walking speed.*

PROCEDURE:

OBSERVATIONS:

ANALYSIS AND CONCLUSION:

End of Lesson 2

LESSON RECORD FORM

1260 Physics 10

Revised 89/02

FOR STUDENT USE ONLY

Date Lesson Submitted ____________________

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(If label is missing
or incorrect)

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Additional Grading
E/R/P Code: __________

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Assignment Code: __________

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ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

KINEMATICS

In Lesson 2 you studied uniform motion which will be quite useful in the study of kinematics. However for most objects the motion is not uniform i.e. the object may start, speed up, slow down and stop. So the objects may accelerate, decelerate or retard. Remember deceleration or retardation is nothing but negative acceleration. The direction of motion of a body has an important place in kinematics but we will be ignoring that at the present. You will learn about it in Lesson 5. So we shall deal with the study of acceleration ignoring the direction part of it.

Read sections 2.5 and 2.6, pages 16-19 of the textbook.

A body can move with a uniform speed or with a variable speed. If it is moving with a uniform speed the acceleration is zero. If it is moving with a variable speed, it will have acceleration. If after every second there is an equal amount of increase or decrease in speed, then the acceleration is called uniform acceleration. To find uniform acceleration, you need to know the initial speed, the final speed and the time elapsed. To put this in an equation, you will write

$$\text{acceleration} = \frac{\text{final speed - initial speed}}{\text{time elapsed}}$$

or

$$\boxed{a = \frac{\Delta v}{\Delta t}}$$

Since the units of v are m/s, the units of Δv will be m/s and consequently units of 'a' will be

$$a = \frac{\Delta v}{\Delta t} = \frac{m/s}{s} = m/s^2$$

EXAMPLE 1 A car starting from rest undergoes uniform acceleration, and attains a speed of 16 m/s in 8.0 s. Find the acceleration.

Given: $v_i = 0$
$v_f = 16$ m/s
$\Delta t = 8.0$ s

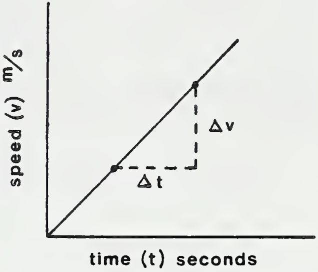
To find: $a = ?$

Solution: $a = \frac{\Delta v}{\Delta t} = \frac{16 \text{ m/s} - 0 \text{ m/s}}{8.0 \text{ s}} = 2.0 \text{ m/s}^2$

Speed-Time Graph for Uniform Acceleration

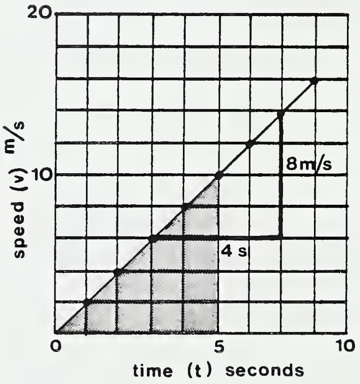
If you plot a speed-time graph for a body moving with uniform acceleration you will obtain a straight line as shown in Fig. A. From your knowledge of slope of a straight line, if you find the slope of this line, it will be $\Delta v/\Delta t$, which by definition is acceleration. So the slope of the line obtained from a speed-time graph will give you the acceleration of the body. Let us use Example 1 to verify this. The time and speed chart of the car will be as follows:

Fig. A



t (s)	v (m/s)
0	0
1.0	2.0
2.0	4.0
3.0	6.0
4.0	8.0
5.0	10
6.0	12
7.0	14
8.0	16

Fig. B



If you plot the graph, you will get a straight line as shown in Fig. B. The slope of the line will be,

$$a = \frac{(14 - 6.0)\ \text{m/s}}{(7.0 - 3.0)\ \text{s}} = \frac{8.0\ \text{m/s}}{4.0\ \text{s}} = 2.0\ \text{m/s}^2$$

So you can see that you came up with the same answer as you had when you solved it mathematically. Also if you want to find the distance travelled by the body in a particular time, you will just find the area under the graph. So distance travelled by the car in 5.0 s in Example 1 will be the shaded area shown in Fig. B. You must have noticed that the shaded area is triangular. So you need to know the formula to find the area of a triangle, if you want to find the distance travelled.

$$\text{Area of triangle} = \tfrac{1}{2} \times \text{base} \times \text{height}$$

Therefore distance travelled by the car in Example 1 in 5.0 s will be,

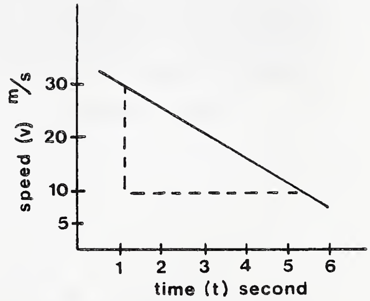
$$\Delta x = \tfrac{1}{2} \times 5.0\ \text{s} \times 10\ \text{m/s}$$

$$= 25\ \text{m}$$

If the speed-time graph has a negative slope i.e. the line falls to the right as shown in Fig. C, the acceleration of the body will be negative. Therefore in Fig. C the acceleration will be,

$$a = -\frac{20\ \text{m/s}}{4\ \text{s}} = -5\ \text{m/s}^2$$

Fig. C



QUESTIONS

Attempt the following questions. Make sure you show all your work.

1. State three different units that could be used to measure acceleration.

____

____

2. Determine the acceleration in each of the following situations.

   (a) An object starting from rest rolls down a ramp and reaches a speed of 40 m/s in 6.0 s.

(b) A car travelling along a flat road maintains a speed of 60 km/h for 10 min.

(c) A car travelling at 30 m/s applies brakes and stops in 3.0 s.

3. A runner is able to accelerate at 30 m/s^2 from standing rest. What speed will he reach after 0.50 s?

If he continues at this acceleration how long would it take him to reach a speed of 30 m/s?

4. The speed-time graph in Fig. D shows the motion of two uniformly accelerating objects.

   (a) What is the acceleration of each object?
   (b) How far does each object travel in 5 s?

Fig. D

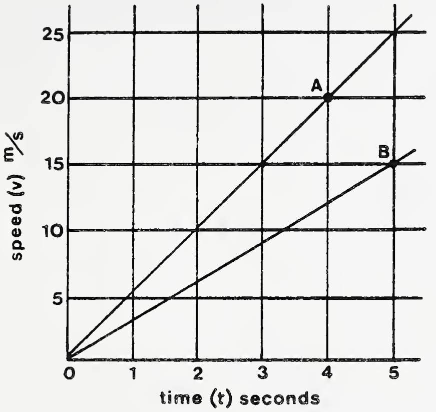
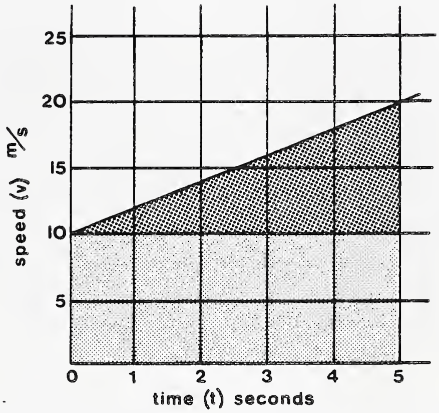


Fig. E



(a)

(b)

5. The speed-time graph in Fig. E also describes the motion of a uniformly accelerating object.

   (a) How does the motion of this object differ from those described in question 4?
   (b) How far does it travel in 5 s? (Hint: Distance travelled is area under the line which in this case is area of the triangle plus the area of the rectangle.)

(a)

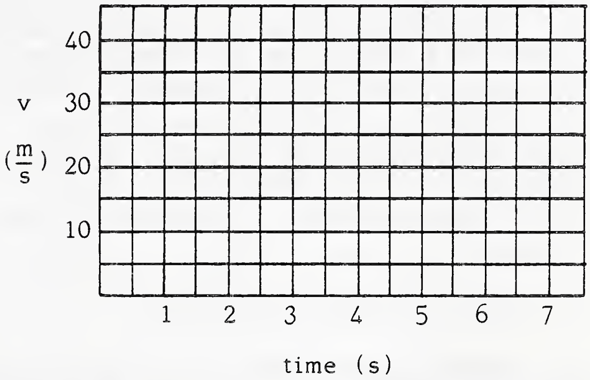
(b)

PROBLEMS

1. A rock starts rolling up a hill at 0.8 m/s. One minute later it is rolling at 0.3 m/s. What is its acceleration?

2. Draw a speed-time graph for a body moving with a uniform acceleration of 5.0 m/s². Initial speed of the body was 10.0 m/s. Also find from the graph the distance travelled by the body in 6.0 s. (Hint: Do not forget to find total area under the line.)

speed	time
10 m/s	0 s
45 m/s	7 s



distance travelled =

3. Initial speed of a body moving with a uniform acceleration of 4.0 m/s² is 10.0 m/s.

(a) Find the speed after 8.0 s.
(b) After what time will its speed become 40.0 m/s?

(a)

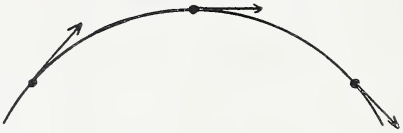
(b)

Instantaneous and Average Speed

Read section 2.7, pages 20-22 of the textbook.

In describing the curvilinear motion of a particle, it sometimes becomes necessary to specify its instantaneous speed.

Fig. F



As shown in Fig. F the instantaneous speed of a particle at any given point in its path is obtained by drawing a tangent to the curve at the point in question. The speed of the particle as it passes that point is the instantaneous speed. It is mathematically represented by the familiar equation, $v = \frac{\Delta x}{\Delta t}$, where Δt is made as small as possible.

An object moving with an acceleration will not have the same speed all the time. For example, if you are travelling in a car from Edmonton to Calgary, a distance of 290 km, you may be driving at 40 km/h, 60 km/h, 90 km/h or 100 km/h during various times in your drive. These are instantaneous speeds. You may be interested to find the average speed during the trip. So you will note the total time required for the trip and knowing the total distance travelled, your average speed will be,

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

or

$$v_{av} = \frac{\Delta x}{\Delta t}$$

SELF CHECKS

Do questions 13-15, pages 22-23 of the textbook and check your answers with the answers given on page 147 of the textbook. You do not have to send these for corrections.

13. A driver in a car rally travels from Toronto to Vancouver, a distance of 3200 km, in 50 h. Calculate his average speed. If he could maintain this average speed, how long would it take him to circumnavigate the earth at the equator? (You should get 628 h)

14. The speed-time graph on page 22 of the textbook describes motion of a car which starts from rest. Use this graph to determine the distance travelled by the car in 10 s.

    Determine also the average speed for the first 10 s of this trip.

15. Examine the distance-time graph in Fig. 2.13, page 23 of textbook.

    (a) Describe the illustrated motion in a few sentences.
    (b) Determine the average speed for the 20 s trip.
    (c) Estimate the instantaneous speed after 5 and 15 s.
    (d) Is this an example of uniform acceleration?

(a) ____

____

____

(b)

(c)

(d) ____

Derivation of Algebraic Equations for Uniform Acceleration

Read section 2.8 — 2.10, pages 23-27 of the textbook.

You must have come across the derivation of these four equations of motion:

For a body moving with uniform speed,

1. $v = \frac{\Delta x}{\Delta t} = \frac{d}{t}$

For a body moving with uniform acceleration,

2. $a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t}$ or $v_f = v_i + at$

3. $d = \left(\frac{v_i + v_f}{2}\right)t$

4. $d = v_i t + \frac{1}{2}at^2$

Notice that where your textbook uses a capital 'T' we use lower case 't'. This is done to be consistent with the Physics 30 Data Booklet.

In these equations v is speed, d is distance, t is time, a is acceleration, v_i is the initial speed and v_f is the final speed.

Note: A freely falling body is a body falling under conditions in which air resistance is zero or is so small that it can be ignored. A freely falling body accelerates downwards with an acceleration of 9.8 m/s^2. For a freely falling body, equation 4 becomes

$$d = v_i t + \frac{1}{2}a_g t^2$$

Also there is another very important equation, which is not mentioned in the textbook. i.e.

5. $v_f^2 = v_i^2 + 2\,ad$

The method of derivation of these equations is not very important for you. What is important is that you use these equations in problem solving. The more problems you solve the better you will understand them. Some problems are given below but you can select some from pages 28-31 of the textbook for your practice.

EXAMPLE 2

The initial speed of a body moving with a uniform acceleration of 5.0 m/s^2 is 10.0 m/s. Find the speed after 15 s.

Given: $v_i = 10.0$ m/s

$a = 5.0$ m/s^2

$t = 15$ s

To find: v_f

Solution: $v_f = v_i + at$

$= 10.0\ m/s + 5.0\ m/s^2 \times 15\ s$

$= 10.0\ m/s + 75\ m/s = 85\ m/s$

EXAMPLE 3

The initial speed of a body moving with a uniform acceleration of 3.5 m/s^2 is 12 m/s. Find the distance travelled by the body in 0.50 min.

Given: $v_i = 12$ m/s

$a = 3.5$ m/s^2

$t = 0.50$ min $= 30$ s

To find: $d = ?$

Solution: $d = v_i t + \frac{1}{2}at^2$

$= 12\ m/s \times 30\ s + \frac{1}{2} \times 3.5\ m/s^2 \times (30\ s)^2$

$= 360\ m + \frac{1}{2} \times 3.5\ m/s^2 \times 900\ s^2$

$= 360\ m + 1575\ m$

$= 1935\ m$

$= 1.9 \times 10^3\ m$

EXAMPLE 4

A train starting from a station is moving uniformly gaining speed until after 2 min it acquires a speed of 100 km/h. What is the distance travelled by the train during this time interval?

Given: $v_i = 0$

$v_f = 100 \text{ km/h}$

$t = 2 \text{ min} = \frac{1}{30} \text{ h}$

To find: $d = ?$

Solution:

$$d = \left(\frac{v_i + v_f}{2}\right)t$$

$$= \left(\frac{0 + 100 \text{ km/h}}{2}\right)\frac{1}{30} \text{ h}$$

$$= \frac{100}{60} \text{ km} = 1.7 \text{ km} = 2 \text{ km}$$

EXAMPLE 5

A stone is dropped from a height of 980 m. How long does it take to reach the ground and what is its speed when it reaches the ground?

Given: $v_i = 0$

$d = 980 \text{ m}$

$a_g = 9.8 \text{ m/s}^2$

To find: t and v_f

Solution:

$$d = v_i t + \tfrac{1}{2} a_g t^2$$

$$980 \text{ m} = 0 + \tfrac{1}{2} \times 9.8 \text{ m/s}^2 \times t^2$$

$$4.9 t^2 = 980 \text{ s}^2$$

$$t^2 = 200 \text{ s}^2$$

$$t = \sqrt{200} \text{ s}$$

$$= 14 \text{ s}$$

$$v_f = v_i + a_g t$$

$$= 0 + 9.8 \text{ m/s}^2 \times 14 \text{ s} = 137.2 \text{ m/s}$$

$$= 1.4 \times 10^2 \text{ m/s}$$

EXAMPLE 6

A stone is dropped from a tall building. The stone hits the ground with a speed of 3.0×10^1 m/s. From what height was the stone dropped?

Given: $v_i = 0$ m/s
$a_g = 9.8$ m/s^2
$v_f = 30$ m/s

To find: $d = ?$

Often you can save some calculations by selecting the more suitable formula. You can see the two solutions here. The alternate solution saves some steps though both solutions are equally correct.

Solution: $v_f = v_i + a_g t$

$$\begin{aligned}
t &= \frac{v_f - v_i}{a_g} \\
&= \frac{30\,\mathrm{m/s} - 0\,\mathrm{m/s}}{9.8\,\mathrm{m/s^2}} \\
&= 3.06\,\mathrm{s}
\end{aligned}$$

$$\begin{aligned}
d &= v_i t + \tfrac{1}{2} a t^2 \\
&= (0\,\mathrm{m/s})(3.06\,\mathrm{s}) + \tfrac{1}{2}(9.8\,\mathrm{m/s^2})(3.06\,\mathrm{s})^2 \\
&= 0\,\mathrm{m} + 45.88\,\mathrm{m} \\
&= 45.88\,\mathrm{m} \\
&= 46\,\mathrm{m} \quad \text{(rounded to 2 S.D.)}
\end{aligned}$$

The stone was dropped from a height of 46 m.

Alternate Solution: $v_f^2 = v_i^2 + 2a_g d$

$$\begin{aligned}
d &= \frac{v_f^2 - v_i^2}{2a_g} \\
&= \frac{(30\,\mathrm{m/s})^2 - (0\,\mathrm{m/s})^2}{2(9.8\,\mathrm{m/s^2})} \\
&= \frac{900}{19.6}\,\mathrm{m} \\
&\doteq 45.9\,\mathrm{m} \\
&= 46\,\mathrm{m} \text{(rounded to 2 S.D.)}
\end{aligned}$$

PROBLEMS Please show all your work.

1. A car travelling at 40 m/s accelerates uniformly to 60 m/s. Determine the average speed if the time of acceleration was 5.0 s. What would be the average speed if the time interval of the acceleration was 10 s?

2. A body starting from rest accelerates uniformly and attains a speed of 30 m/s after travelling a distance of 45 m. Find the acceleration of the body and the time required to travel this distance.

3. A stone is dropped from the top of a hi-rise. It reaches the ground in 6.0 s. Find the height of the hi-rise.

4. A car starts up from rest, accelerates uniformly for 1 min and acquires a speed of 30 km/h. What will be the distance travelled by the car in this time interval?

5. A balloon is falling at the rate of 80.0 m/s and when it is at a height of 8.0×10^2 m, a stone is dropped from it. With what speed does it hit the ground? (Hint: The stone does not begin to fall from rest. It will have the same initial speed as the balloon, that is, 80.0 m/s.)

Lesson Summary

Instantaneous speed is the speed of an object at a particular instant in time and is numerically equal to the slope of the tangent to the curve on a distance-time graph.

Average speed is the total distance travelled divided by total time taken.

Acceleration is the rate of change of speed.

Uniform acceleration occurs when an object changes its speed at a constant rate.

The speed-time graph for uniformly accelerated motion is a straight line and the slope of the line equals the acceleration. The area under the line for a certain time-interval equals the distance travelled during that time-interval.

The algebraic equations of motion are

1. $v = \frac{\Delta x}{\Delta t} = \frac{d}{t}$, for a body with uniform speed.

And for a body moving with uniform acceleration,

2. $a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t}$

   or $v_f = v_i + at$

3. $d = \left(\frac{v_i + v_f}{2}\right)t$

4. $d = v_i t + \frac{1}{2}at^2$

5. $v_f^2 = v_i^2 + 2ad$

EXPERIMENT #3

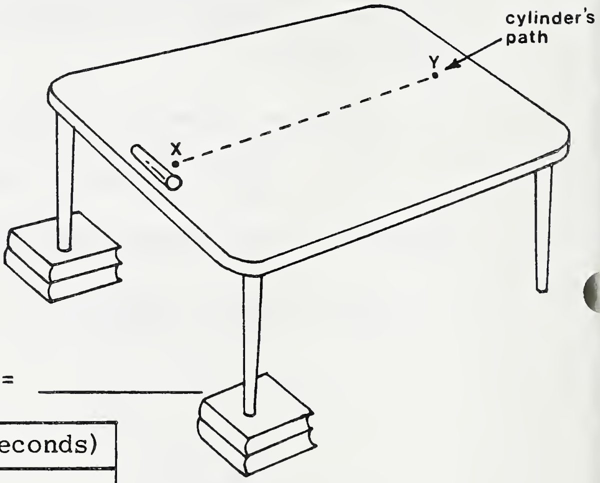
AIM: To find the acceleration of a uniformly accelerated body.

APPARATUS: Take a table with a smooth surface. (A coffee table or dining table will serve your purpose) You will also need a cylindrical object with a smooth surface. (A glass vial or a rolling pin or a tin can will serve the purpose.) For accurate measurement of time a stop watch is required. But if you do not have access to a stop watch, you can use your wrist watch or time clock with a seconds-hand on it.

PROCEDURE: Put a couple of books of the same height under the two legs of the table as shown in the Fig. G. Mark two points X and Y in a straight line on the table. Place the cylindrical object on this line at the point X and give it a slight push. Note the time required by the cylindrical object to travel the distance between X and Y.

Repeat the observation at least five times.

Fig. G



OBSERVATIONS: Distance XY (cm) = ____________

Trial	Time Taken (seconds)
1	
2	
3	
4	
5	

$$\text{Average Time taken} = \frac{\text{SUM of the times of all the trials}}{\text{number of trials}}$$

= ____________

= ____________

ANALYSIS: Apply the equation $d = v_i t + \frac{1}{2} a t^2$ to find 'a' using the average value of the time. Assume that $v_i = 0$.

CONCLUSIONS:

____

____

End of Lesson 3

LESSON RECORD FORM

1260 Physics 10

Revised 89/02

FOR STUDENT USE ONLY

Date Lesson Submitted

Time Spent on Lesson

(If label is missing or incorrect)

File Number

Lesson Number

FOR SCHOOL USE ONLY

Assigned Teacher:

Lesson Grading:

Additional Grading E/R/P Code:

Mark:

Graded by:

Assignment Code:

Date Lesson Received:

Lesson Recorded

Student's Questions and Comments

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ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

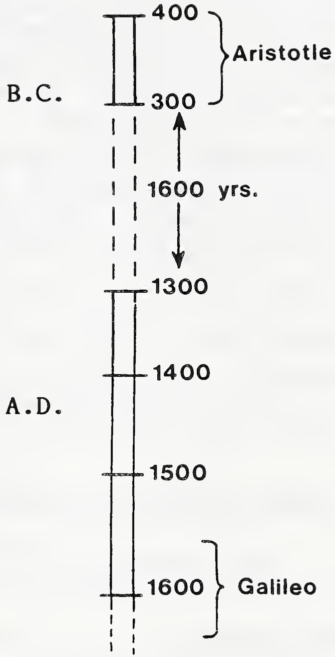
Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

GALILEO AND MOTION

Physics in 1550

Galileo Galilei, an Italian, lived from 1564 to 1642. At the time of his birth, the beliefs commonly held about physics, especially the motion of objects, were those of Aristotle who had lived almost 2000 years before. Aristotle's views, lost to Europe during its early history, were recovered about 1200 A.D. It was not long until they became commonly accepted as the explanation for the motions of bodies.



Let us review from Lesson 1 the main outline of Aristotle's ideas about the physical world.

Aristotle adopted the idea, common among the Greeks, that in or near the earth there were four elements — earth, air, fire and water. Each of these elements has its natural place. Earth is at the centre. Water is next on the surface of earth. Air is above the surface of the earth. Fire rises above all three. Each element seeks its "natural place." One kind of motion, natural motion, occurs when an element moves toward its natural place. A falling stone is in natural motion seeking to return to its natural place, the earth. Violent or unnatural motion occurs when an object is moved away from its natural place. Objects that fall to the earth fall:

(a) at constant speed;

(b) faster if their mass is greater;

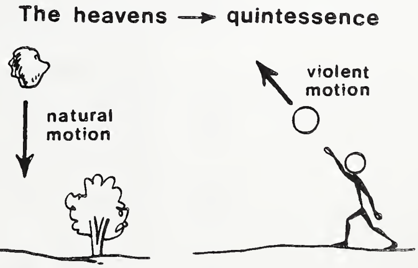
(c) slower as the resistance of the medium increases.

earth

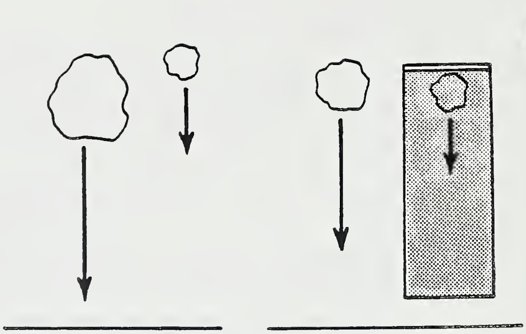
air

water

fire



It is interesting how closely Aristotle's ideas compare with our "common sense" understandings. Earth, water, air and fire roughly correspond to solids, liquids, gases and energy in our understandings of physical substances. We observe that heavy objects very often fall faster than lighter objects. We know also that objects fall more slowly in water. Thus Aristotle's views are not to be written off simply as incorrect and undesirable. Yet there were weaknesses. Galileo was to help make a new start in understanding how to learn about the physical world.



Heavy object falls faster

Object in air falls faster than object in water

In a given situation an object falls at a constant speed.

Galileo Studies Free Fall

Read section 3.1, pages 33 and 34 of the textbook.

QUESTIONS

1. Before Galileo's time there were several attitudes that were necessary to support the growth of science after Galileo. Which of the following is one of those attitudes?

   (a) Everything has its natural place.
   (b) It is important always to begin with principles, then figure out a specific explanation from a principle.
   (c) It is important to know the quality of a body in order to know how it will move.
   (d) It is important to have confidence in the use of reason and thought to solve problems. ________

2. In the Renaissance during the 1500's, scholars discovered with much interest and excitement the works and accomplishments of the ancient Greeks and Romans. But the scientific revolution did not get started until near the end of the Renaissance. Why was this so?

   (a) Most effort was devoted to discovering as much of the ancient world as possible.
   (b) The ancient understandings of science were good enough for the tools of study that were available then.
   (c) There were too few good universities to encourage the study of science.
   (d) Science was not one of the disciplines to which the ancients gave any attention. ________

3. Galileo's earliest studies were in

   (a) physics.
   (b) astronomy.
   (c) medicine.
   (d) engineering. ______

4. Galileo's second set of studies was in

   (a) physics of motion.
   (b) medicine.
   (c) astronomy.
   (d) mathematics. ______

5. What major contribution did Galileo make in the study of the natural world?

   (a) An emphasis on quantitative observation.
   (b) Experimental proof of philosophical principles.
   (c) A pendulum device for measuring time.
   (d) Team work in organizing scientific research. ______

6. In the section that you have just read what hints do you have about Galileo's personality? What kind of person was he?

   ____

   ____

Galileo's Two New Sciences

Read section 3.2, pages 35-37 of the textbook.

QUESTIONS

1. Mechanics as a branch of physics is best defined as

   (a) the operation of gears, pulleys and levers.
   (b) the study of interaction between forces and matter.
   (c) the study of mathematics as it applies to physics.
   (d) the use of observation in studying motion. ______

2. Galileo wrote a book on astronomy but did not continue in this area; instead he took up the study of the motion of bodies on earth. Why?

   (a) His acceptance of Copernicus' astronomy produced conflict with the Inquisition.
   (b) He was interrupted by being given a teaching post at another university.
   (c) He had gone as far in studying astronomy as he could have at the time.
   (d) He lacked financial support for continuing work in astronomy. ________

3. Galileo's books were written in the form of a

   (a) poem.
   (b) novel.
   (c) play.
   (d) dialogue. ________

4. Here is a summary of Galileo's reasoning concerning Aristotle's idea that objects fall at differing speeds:

   Take two stones — a large one, stone A and a small one, stone B.

   Aristotle says that stone A has a natural, fast speed at which it will fall. Stone B has a natural, slower speed at which it will fall.

   Unite stone B with stone A as they fall.

   Stone B will slow up stone A.

   Stone A will speed up stone B.

   The resultant speed will be a new speed half way between the natural speeds of stone A and stone B.

   But stone A and stone B together are heavier than stone A.

   Therefore they move faster than stone A.

   But we said before when they are united that they should move slower than stone A (halfway between the natural speeds of stones A and B).

   There is a contradiction.

   Therefore stones A and B cannot fall at different speeds.

   Does this argument make sense to you?

If it does make sense why do heavier objects, in many cases, actually fall faster than lighter ones?

The argument failed to take air resistance into account.

5. In the dialogue, middle of page 36 of the textbook, Salviati notes that some people call attention to the fact that a lighter object often does take a slightly longer time to reach the ground than a heavier one. A larger rock reaches the ground a few centimetres ahead of a small pebble. But, according to Salviati, this is not a serious objection to the idea that all bodies fall at the same rate. Why?

Why Study the Motion of Freely Falling Bodies?

Read section 3.3, pages 37 and 38 of the textbook.

QUESTIONS

1. What were two characteristics of Galileo that made him an outstanding scientist?

Galileo Chooses a Definition of Uniform Acceleration

Read section 3.4, pages 38-40 of the textbook.

QUESTIONS

1. What is the order of steps in which Galileo proposed to study motion?

   (a) prediction, testing, definition, assumption
   (b) prediction, definition, assumption, testing
   (c) assumption, prediction, definition, testing
   (d) definition, assumption, prediction, testing

2. (a) How did Galileo define uniform motion (uniform speed, page 38)?

(b) How would you show speed in mathematical symbols?

(c) How did Galileo define uniform acceleration?

(d) How would you show acceleration in mathematical symbols?

3. Galileo's main concern in studying motion was to

(a) discover the cause of the motion of falling bodies.
(b) determine the rate at which bodies fall.
(c) accurately describe the way in which bodies fall.
(d) prove Aristotle wrong.

4. There is another simple definition of uniform acceleration that we could use (other than the one given in 2(c)). What is it?

What are the mathematical symbols for this definition?

$$a = \frac{\Delta v}{\Delta d}$$

5. Why did Galileo choose the definition in #2 on page 5 rather than the one in #4 above?

The definition in #2 was seen to be more useful.

Galileo Cannot Make a Direct Test But Mathematics Suggest a Possible Indirect Test

Read sections 3.5 and 3.6, pages 40 - 41 of the textbook.

QUESTIONS

1. Why could not Galileo make a direct test of the idea that $a = \frac{\Delta v}{\Delta t}$ is constant for a falling body?

(a) The time of fall was too short and the constantly changing velocity was difficult to measure directly.

(b) While t was easily measurable for a given point in the fall, v was not.

(c) Galileo would have been hindered in such an experiment by the strong opposition of his colleagues.

(d) For an object falling for a long enough time to measure t accurately, air resistance would become a major factor in the experiment.

______

2. As scientists often do, Galileo called upon mathematics to give him some help. If acceleration is defined as Galileo defined it $\left(a = \frac{\Delta v}{\Delta t}\right)$ then distance travelled is given by $d = v_i t + \frac{1}{2}at^2$. You have already met this formula in Lesson 3.

$d = v_i t + \frac{1}{2}at^2$

What does this formula become when it applies to a falling body dropped from rest?

3. What can be said about a body's motion when

(a) the ratio $\frac{d}{t}$ is constant?

If $\frac{d}{t} = k$

(b) the ratio $\frac{d}{t^2}$ is constant?

If $\frac{d}{t^2} = k$

Galileo Turns to an Indirect Test

Read section 3.7, pages 42-43 of the textbook.

QUESTIONS

1. Restate the new hypothesis that Galileo made to test his idea that 'a' is constant for a falling body.

____

____

____

____

The New Hypothesis - More Modest But Testable.

2. Describe briefly the steps in Galileo's experiment.

1. Cut a channel in a piece of wood 6.12 m long, 0.51 m wide, and 0.06 m thick. The channel should be about 2 cm wide. Polish the groove and line it with smooth parchment.

2. Slope the board by lifting it about 1 m high at one end.

3. Roll a smooth, round bronze ball down the length of the board noting the time required.

4. Observe the time required to roll the ball $\frac{1}{2}$, $\frac{2}{3}$, etc. of the length of the board.

5. Complete and compare $\frac{d}{t^2}$ for each of the measurements.

3. Below is a set of datafrom an experiment similar to Galileo's. Show that $\frac{d}{t^2}$ is nearly a constant for these values.

Length of board = 8.0 m

Ht. of board = 5.0 m

d	t	t^2	$\frac{d}{t^2}$
8.0 m	5.1 s		
2.0 m	2.5 s		
6.0 m	4.4 s		
5.0 m	4.0 s		
3.0 m	3.1 s		

Approximately, what is the constant value for $\frac{d}{t^2}$? __________

4. In Galileo's theory of falling bodies, the cause of the behavior of the falling bodies is considered to be

   (a) a power of "force" which is put into a body by the hand or other object that releases it.
   (b) the natural tendency of bodies to move horizontally with uniform motion, vertically with uniform acceleration.
   (c) the inherent simplicity of nature.
   (d) undetermined by Galileo's investigation and irrelevant, since the theory is merely concerned with correct mathematical description of the behavior of falling bodies.
   (e) an action exerted upon the body by a force which is present at all places about the earth and which acts in the direction of the earth's centre. ________

How Valid Was Galileo's Procedure?

Read section 3.8, pages 43-44 of the textbook.

QUESTIONS

1. The main reason why we might doubt the validity of Galileo's procedure is

   (a) in Galileo's experiment the ball was actually rolling rather than sliding, and therefore his results cannot be extrapolated to the case of free fall.
   (b) his measurement of distance may not have been accurate.
   (c) he used too large an angle of inclination.
   (d) his measurement of time may not have been sufficiently accurate. ________

2. Describe a more accurate and more valid way of testing Galileo's hypothesis that a body falls with uniform acceleration. Use any apparatus you wish but try to make it as simple as possible. Include a diagram if you can.

The Consequences of Galileo's Work on Motion

Read section 3.9, pages 45-47 of the textbook.

QUESTIONS

1. What were the two major results of Galileo's work on motion?

   (a) The indirect evidence that masses of different sizes fell at the same rate called Aristotle's theory of motion into question.
   (b) The first calculation of the actual value of free fall acceleration was made.
   (c) A mathematical description of accelerated motion was made that could be used for prediction of behavior of moving objects.
   (d) Galileo had proved conclusively that falling bodies move with uniform acceleration. ________

2. What was the most central problem for science during Galileo's time?

   (a) understanding the pattern of motion of falling bodies
   (b) understanding the pattern of motion of bodies moving across the earth's surface
   (c) understanding how mathematics could be used to describe scientific phenomena
   (d) understanding how the motions of the sun, earth, planets and stars are related to each other ______

3. What are the steps involved in Galileo's method of doing research?

   ____

   ____

   ____

   ____

   ____

While these steps are usually followed closely in scientific research they allow much flexibility within the steps. For example:

1. Hypotheses may be derived in a number of ways — from results of a previous experiment, an unexpected observation, a specific problem presenting itself through circumstances or a desire for a simpler hypothesis.
2. The experimental data can agree with the prediction over a wide range of error with sometimes 50% error acceptable.

4. The method outlined above is still used today by scientists. Why?

   (a) Out of respect for Galileo's towering intellect and achievements.
   (b) It produces results that can successfully be used for further prediction and discovery.
   (c) It is the only sure way of proving without question of doubt a given relationship or proposition.
   (d) It is successful in doing away with error in the mathematical description of the physical world. ______

5. In what sense could Galileo be considered the "father of modern science"?

____

____

____

Measuring the Acceleration of a Freely Falling or Freely Rolling Body

Read section 3.10, pages 47-49 of the textbook.

It is not a simple task to take careful measurements of an accelerating body. However, it is possible, using simple equipment to show that a body acted upon by the earth's gravitational field accelerates in a uniform fashion. In this section an experiment will be done to show that there is a direct relationship between velocity and distance as a body accelerates.

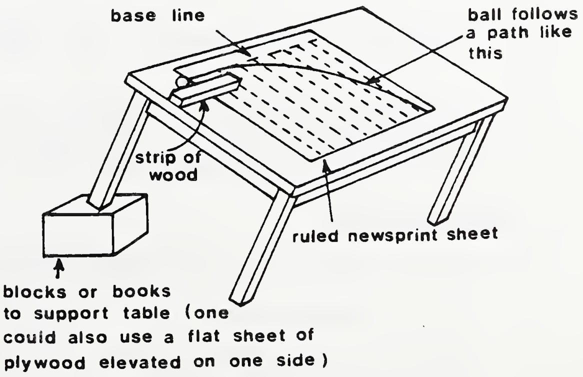
EXPERIMENT #4

You will need the following equipment for this experiment:

- a table top or other flat movable surface at least 1 m x 1 m
- newsprint sheet 38 cm x 56 cm (you can use an old newspaper)
- a steel ball (or a large glass marble)
- books or small area boards to prop up one side of the table

In this experiment you will be rolling a ball across an inclined plane. The ball is given an initial horizontal velocity. Two things are assumed:

1. The horizontal and vertical velocities can be considered entirely separately.
2. The horizontal velocity of the ball stays constant. This means that the ball crosses the ruled lines in equal time intervals.

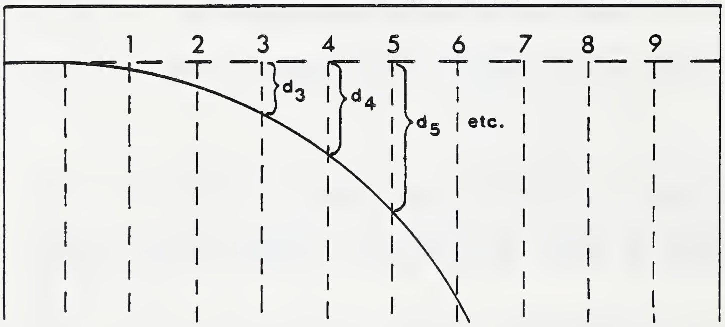

base line
ball follows a path like this
strip of wood
ruled newsprint sheet
blocks or books to support table (one could also use a flat sheet of plywood elevated on one side)

PROCEDURE A

Do this or Procedure B below.

1. Rule off the sheet of newsprint the long way in intervals of 3.5 cm.
2. Fasten the newsprint to the table surface and fix a rule or strip of wood as shown in the diagram.
3. Practise rolling the ball down the plane by giving it a nudge along the strip of wood until the ball rolls down near the far corner of the sheet.
4. Dip the ball in some water, colored with a few drops of ink, and roll the ball as before to make a track on the paper. Make several trials if the first one does not work out well.
5. Trace the path of the ball with a line drawn by a pen or pencil. Try to follow the centre of the ball's track.
6. Draw a base line through the level at which the ball started. If the track has a width, draw the base line through the centre of the track. Also make sure that it crosses the ruled lines at right angles.

   By now you should have aparabola as shown below. You don't have to send this newsprint in.



7. Complete the table of data in which (d) and other data are given.

   Calculate the following: Δd, $\frac{\Delta d}{\Delta t} = v$, $\frac{\Delta v}{\Delta t} = \frac{\Delta\left(\frac{\Delta d}{\Delta t}\right)}{\Delta t} = a$. Assume that the unit of time is 1 second, the time that it takes the ball to cross each of the 3.5 cm spaces. The table with sample data appears in the OBSERVATIONS space on the next page.

PROCEDURE B

1. Put a small hole into the bottom of the side of an empty milk carton.
2. Fill it with water
3. Note the parabola shape of the water flowing out of the milk carton.
4. Do number 7 of Procedure A.

OBSERVATIONS:

DATA CHART (for completion by students)

Time (second)	Distance (d) (cm)	Δd (cm)	$v = \frac{\Delta d}{\Delta t}$ (cm/time unit)	Δv (cm/time unit)	$a = \frac{\Delta v}{\Delta t}$ (cm/time unit^2)
0	0 cm				
1	2.5 cm	2.5 cm	2.5 cm/s	5.0 cm/s	5.0 cm/s^2
2	10.0 cm	7.5 cm	7.5 cm/s		
3	22.5 cm	12.5 cm			
4	40.0 cm	17.5 cm			
5	62.5 cm				
6	90.0 cm				
7	122.5 cm				

ANALYSIS AND CONCLUSIONS:

What conclusions would you expect from these results regarding the acceleration?

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PROBLEMS

1. A research creature travelling on a space exploration expedition lands on the planet Megapluton. With precise equipment he measures the free fall on the planet by observing a falling object. His data are recorded below:

Time (in seconds)	Distance (in metres)
0.0	0.00
0.5	3.04
1.0	12.15
1.5	27.35
2.0	48.56
2.5	75.41
3.0	109.29
3.5	148.75

(a) What is the average velocity between 0.0 seconds and 1.0 seconds?

____

(b) What is the final velocity at 2.0 seconds?

$$d = \left(\frac{v_i + v_f}{2}\right) t \qquad \text{since } v_i = 0 \qquad d = \frac{v_f t}{2} \quad \text{or} \quad v_f = \frac{2d}{t}$$

$$v_f = \frac{48.56\text{m} \times 2}{2.0 \text{ s}} = 49 \text{ m/s} \quad \text{(to 2 significant digits)}$$

(c) Find Δd between 1.0 and 2.0 seconds.

$$\Delta d = 48.56 \text{ m} - 12.15 \text{ m} = 36.41 \text{ m}$$

(d) Find Δd between 2.0 and 3.0 seconds.

(e) Find $\frac{\Delta d}{\Delta t}$ between 1.0 and 2.0 seconds.

$$\frac{\Delta d}{\Delta t} = \frac{36.41 \text{ m}}{1.0 \text{ s}} = 36 \text{ m/s}$$

We show 2 S.D. since the time is shown with only 2 S.D.

(f) Find $\frac{\Delta d}{\Delta t}$ between 2.0 to 3.0 seconds.

(g) Now, find $\frac{\Delta\left(\frac{\Delta d}{\Delta t}\right)}{\Delta t} = a_g$, for the $\frac{\Delta d}{\Delta t}$'s you calculated in (e) and (f).

Hint: $\Delta t = 1.0$ seconds

(h) Now use only the last entry t = 3.5 seconds, d = 148.75 metres to find a_g.

Hint: $d = v_i t + \frac{1}{2} a t^2$ and $v_i = 0$

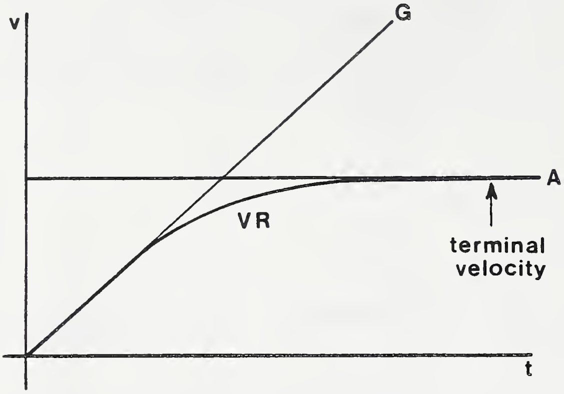
(i) What does this tell you about the gravitational force on Megapluton?

____

____

____

2. All bodies, when falling through air, eventually reach a terminal speed and continue to fall with this constant speed. The curved line (VR) in the speed-time graph below shows the actual behavior of a body falling through the air, and the straight lines represent the kind of motion that Aristotle (A) and Galileo (G) claimed represented the motion of a falling body.



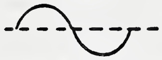
(the horizontal line)

Place **G**, **A**, or **VR** in the appropriate blank.

__________ The body falls with uniform speed.

__________ The body falls with uniform acceleration.

__________ Initially the body falls with uniform acceleration. Then the acceleration gradually decreases until the body reaches a terminal velocity.

3. Along the side of this page there is a wavy line made by a marker mounted on an oscillating arm. The arm has a constant rate of vibration and therefore the time for each full wave is constant and is 0.050 s. (a full wave looks like this: ). The paper on which the wavy line was made was originally attached to a body falling from rest. From the wavy line data make at least three calculations of acceleration due to gravity. [Hint: Use the formula $d = v_i t + \frac{1}{2} a t^2$. With $v_i = 0$, it becomes $d = \frac{1}{2} a t^2$ and acceleration is given by $a = \frac{2d}{t^2}$]

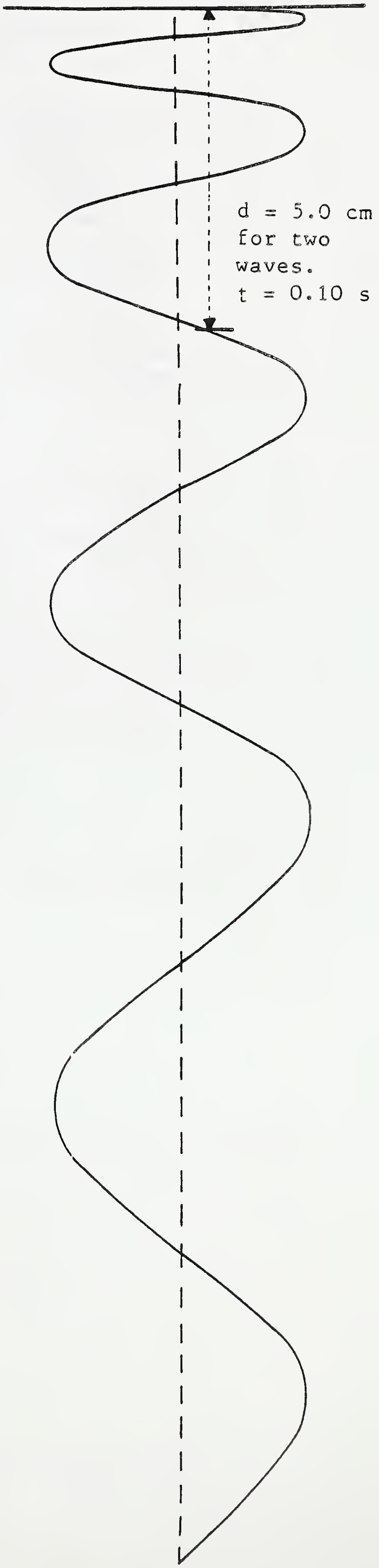
(a) Using the sample measurements on the diagram d = 5.0 cm = 0.050 m, t = 0.10 s

$a = \frac{2d}{t^2} = \frac{2(0.050\ m)}{(0.10\ s)^2} =$ ____________ m/s^2

Complete the above calculation and do two more below.

(b)

(c)



Lesson Summary

In the 16th century the standard understanding of motion came from Aristotle the ancient Greek philosopher. Galileo challenged this understanding by proposing a new means of investigating natural phenomena. One aspect of this new means was the use of mathematical description. Another was the procedure of testing predictions by careful observation of nature. Galileo's experiment with the rolling ball did not indisputably prove that all objects fall at constant acceleration. Nor did he actually calculate acceleration due to gravity. His experiment only pointed toward a new way of discovering relationships in nature. Thus what happened in the 16th century was not a revolution in the way of doing things so much as it was a revolution in what was going on in the minds of scientists. They were discovering a new way of looking at the world.

Galileo's method included four important steps. He first used mathematics to describe a possible kind of motion. Then he assumed that this was a good description of motion in free fall. From this he predicted some results that should follow from the description. And finally he tested the prediction to determine its usefullness and accuracy.

Galileo discovered in his rolling ball experiment that the motion of the ball did indeed involve constant acceleration and that it was possible and likely that freely falling bodies would behave in much the same way. This discovery paved the way for the rapid growth of science that began with Galileo's time.

End of Lesson 4

LESSON RECORD FORM

1260 Physics 10

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MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

MOTION AND DIRECTION

Describing Motion

Read the first part of Chapter 4, pages 53-54, up to section 4.1.

Note the following statement from the textbook:

> "An object is described as being in motion with respect to an observer if a line joining the object to the observer changes in either length or direction."

To help in understanding how this allows a person to describe motion, we can think of what happens when two objects are connected together by something like a line, such as a string. For example, suppose you have a weight on a string and you hold the weight and string in your hand. We can think of the string joining the weight (the object) to you (the observer) as being similar to the line. While you hold the string and weight in your hand, the string does not change in length or direction, so you can say that the weight is at rest with respect to you. Next, suppose you drop the weight, letting the string slip through your fingers until about 50 cm of string has been released. Then, you tighten your grasp on the string and the fall of the weight stops. While it was falling, the weight was in motion downward with respect to you. The increasing length of the string as the weight falls would be similar to the increasing length of a line between you and the weight. In addition, the change in length occurs in a downward direction so that you can describe the motion as being downward.

Now, suppose you hold the length of the string constant, at 50 cm and you twirl the weight in a circle above your head. With respect to your hand, the length of the line between your hand and the weight does not change. However, direction is changing continuously as the weight whirls around. Thus, even though the length of the line does not change, since its direction is changing, the weight must be considered to be in motion with respect to you.

When it is said that an object is in motion with respect to an observer, this means that the observer is considered to be a reference point which is at rest. This is done in order to make it easier to describe the motion; it is not a way of saying that the observer is not moving. It is just a convenient way of defining motion.

At one time it was believed that it was possible to find a point that was perfectly at rest (or absolutely at rest). It was believed that there was something called the aether (pronounced eether) which was a kind of "non-material substance" which filled space and which was a fixed frame of reference throughout space. If a body were absolutely at rest, this meant that it did not move with respect to the aether. However, eventually through experiments with light, the existence of the aether was brought into doubt, and the idea was discarded. This also resulted in elimination of the idea that a body could be absolutely at rest — since it was necessary to have a universal frame of reference in order to define the idea of absolute rest.

The idea of the aether is useful because it demonstrates a very important point: motion must be defined with respect to something, such as the centre of the earth, or the surface of the earth, or the sun. However, you cannot say that your point of reference is absolutely at rest or fixed. You can say only that you have made your observations from a particular point, which you find convenient to use. If you used some other point as your reference point, then you might be able to observe the motion of your previous reference point while pretending that your new point is at rest.

Answer the following questions.

QUESTIONS

1. Describe the motion of each of the following objects relative to a car moving north at 100 km/h with respect to the road.

   (a) A hitchhiker standing beside the road.

   100 km/h south

   (b) Another car heading north at 100 km/h.

   ____

   (c) An airplane overhead flying south at 300 km/h.

   ____

   (d) A car heading north at 101 km/h.

   ____

2. How is motion with respect to an observer described?

____

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3. Is it possible to define the idea of absolute rest physically? Why or why not?

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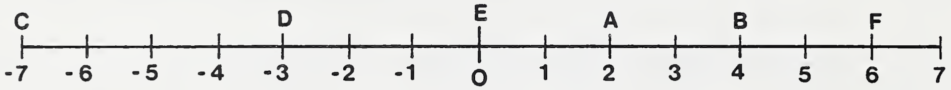
Scalars and Vectors

Read section 4.1 on pages 54 to 56 of the textbook.

Answer the following questions.

QUESTIONS

1. Use the following number line and the sign convention given in the textbook for motion across the page to indicate the displacements of the labelled points from the origin, O.



(a) A ______________ (d) D ______________

(b) B ______________ (e) E ______________

(c) C ______________ (f) F ______________

2. Let us suppose that an object moves along the number line above in the sequence A, B, C, D, E, F. That is, the object starts at A and moves to B, then to C, then to D, then to E, and finally to F.

   (a) What is the displacement of the object with respect to the origin, O?

   ____

   (b) What is the displacement of the object with respect to the starting point, A?

   ____

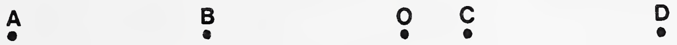
   (c) What is the displacement of the object with respect to point C?

   ____

   (d) What is the total distance travelled by the object along the number line?

   ____

3. The following labelled points represent positions along a line. Point O is the origin, and points A, B, C and D are the positions of an object at various times.



Use a ruler calibrated in cm and the sign convention for motion across a page given in the textbook to do the following things.

(a) Measure in cm the displacements with respect to O of an object at the following points.

A ______________ C ______________

B ______________ D ______________

(b) Measure in cm the displacements with respect to A of an object at the following points.

B ______________ C ______________

O ______________ D ______________

(c) Measure in cm the displacements with respect to D of an object at the following points.

A ______________ O ______________

B ______________ C ______________

4. Underline the correct term for each of the descriptions below.

(a) (Distance/Displacement)

- the distance and direction of the final position from the initial position.

(b) (Velocity/Speed)

- the distance travelled per unit of time.

(c) (Scalar/Vector) Quantities

- have magnitude and direction.

5. A giraffe travels 25.0 m to the left, and then returns a distance of 10.0 m to the right in 5.0 s.

(a) What is its displacement?

(b) What is its average speed?

(c) What is its average velocity?

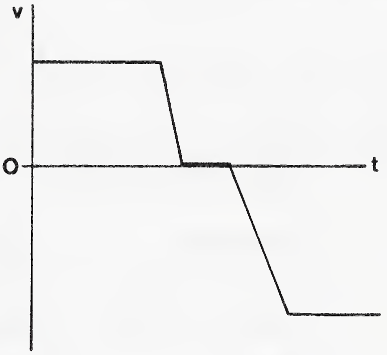
6. A runner completes a circuit of a 3.0×10^2 m track in 50.0 s. This brings the runner back to the starting point. Calculate his average speed and average velocity.

Graphical Analysis

Study section 4.2 on pages 56 to 59 of the textbook.

The velocity-time graph is different from the speed-time graph in that direction is included on the velocity-time graph. See Fig. A. Since the sign convention in the textbook was given as motion to the right being positive, and motion to the left being negative, a velocity directed to the right appears above the horizontal (t) axis, and a velocity to the left appears below the horizontal axis.

Fig. A



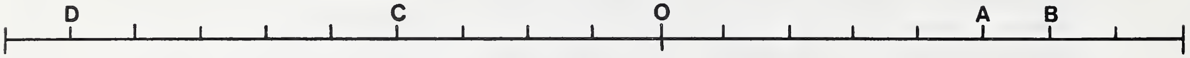
Note that in the textbook the vector quantity (velocity) is represented as a letter (v) with an arrow above it. However, in this lesson the letter (v) has a bar above it. Either of these ways of showing a vector quantity may be used. Often, the letter with the bar above it is considered more convenient to use than the letter with the arrow.

So far we have seen several different kinds of graphs. The number line that we used to represent motion to the right and to the left could be considered to be one type of graph. It is useful because it allows us to describe motion along a straight line – in fact it is a use of one of the first ideas in this lesson: Motion of an object with respect to an observer can be described by considering changes in either length or direction of a line joining the object and the observer. Using a number line to measure changes in position, and using information about time, it is possible to draw position-time graphs, velocity-time graphs, and acceleration-time graphs. As you may have realized earlier in this course, use of such graphs is one way of showing a body's motion. Also, it may be a way to help us understand motion better.

Do the following questions.

QUESTIONS

1. The following line represents the motion of a body along a straight line. The body moves from O to A, from A to B, from B to C, and from C to D.

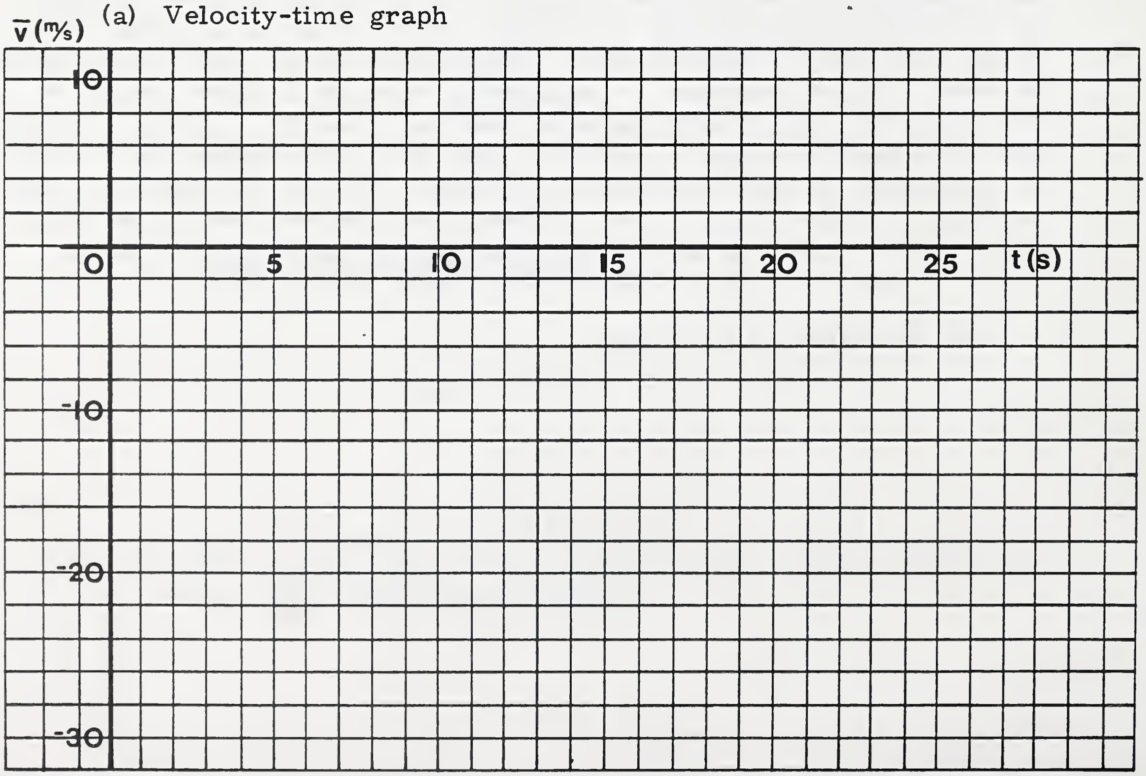


The speeds and time periods involved in this motion are given below.

Positions	Speeds	Time Required
From O to A	10 m/s	5 s
From A to B	From 10 m/s to zero	1 s
At B	zero	2 s
From B to C	From zero to 25 m/s	8 s
From C to D	25 m/s	2 s

Use this information plus the sign convention given in the textbook to draw the following graphs.

(a) Velocity-time graph



(b) Position-time graph

For the position-time graph, it is useful to make a table showing the positions at various times during the motion. The following calculations show how such a table can be made. Go through the calculations and use the results to complete the table on page 11. Then use those results to draw the position-time graph on page 11.

From O to A

This change in position occurs from $t = 0$ s to $t = 5$ s. Velocity is constant at 10 m/s to the right. The formula for finding the position from O to A is $\bar{d} = \bar{v}t$.

$$\begin{aligned}
\text{At } t &= 0 \text{ s}, & \bar{d}_0 &= 10 \text{ m/s} \times 0 \text{ s} = 0 \text{ m} \\
\text{At } t &= 1 \text{ s}, & \bar{d}_1 &= 10 \text{ m/s} \times 1 \text{ s} = 10 \text{ m} \\
\text{At } t &= 2 \text{ s}, & \bar{d}_2 &= 10 \text{ m/s} \times 2 \text{ s} = \underline{\hspace{2cm}} \\
\text{At } t &= 3 \text{ s}, & \bar{d}_3 &= 10 \text{ m/s} \times 3 \text{ s} = \underline{\hspace{2cm}} \\
\text{At } t &= 4 \text{ s}, & \bar{d}_4 &= 10 \text{ m/s} \times 4 \text{ s} = \underline{\hspace{2cm}} \\
\text{At } t &= 5 \text{ s}, & \bar{d}_5 &= 10 \text{ m/s} \times 5 \text{ s} = 50 \text{ m}
\end{aligned}$$

From A to B

This interval lasts for 1 s, from $t = 5$ s to $t = 6$ s. It involves an acceleration since $\bar{v}$ changes from 10 m/s to 0.

$$\bar{a}_{AB} = \frac{\bar{v}_B - \bar{v}_A}{\Delta t} = \frac{0 - 10 \text{ m/s}}{1 \text{ s}} = -10 \text{ m/s}^2$$

The displacement between A and B is given by

$$\begin{aligned}
\bar{d}_{AB} &= \bar{v}_A t_{A-B} + \tfrac{1}{2}\bar{a}_{AB} t^2_{A-B} \\
&= 10 \text{ m/s} \times 1 \text{ s} + \tfrac{1}{2}(-10 \text{ m/s}^2)(1 \text{ s})^2 \\
&= 10 \text{ m} - 5 \text{ m} \\
&= 5 \text{ m}
\end{aligned}$$

So, between A and B, the body has a displacement of 5 m to the right. Hence, its position at 6 s must equal its position at 5 s plus 5 m. At $t = 6$ s, $\bar{d}_6 = 50 \text{ m} + 5 \text{ m} = 55$ m.

At B

At B, the body is stationary for 2 s, from $t = 6$ s to $t = 8$ s.

$$\begin{aligned}
\text{At } t &= 7 \text{ s}, & \bar{d}_7 &= \underline{\hspace{2cm}} \\
\text{At } t &= 8 \text{ s}, & \bar{d}_8 &= 55 \text{ m}
\end{aligned}$$

From B to C

During this interval, there is an acceleration to the left from B to C, for a period of 8 s, from $t = 8$ s to $t = 16$ s.

$$\bar{a}_{BC} = \frac{\bar{v}_C - \bar{v}_B}{\Delta t} = \frac{-25 \text{ m/s} - 0}{8 \text{ s}} = -3.125 \text{ m/s}^2$$

Since the initial velocity for the interval from B to C is zero, we can use the formula $\bar{d} = \frac{1}{2} a t^2$ to find the displacements during the interval. To find the positions during the interval, we must add the position at t = 8 s ($\bar{d}_8$ = 55 m) to the displacements. Therefore, the expression for finding the position at each time during the interval is

$$\bar{d} = \bar{d}_8 + \frac{1}{2}\bar{a}_{BC}\, t^{2}_{B-C}$$

At t = 9 s, t_{B-C} = 1 s

$\bar{d}_9 = 55\ m + \frac{1}{2}(-3.125\ m/s^2)(1\ s)^2$

$= 55\ m - 1.6\ m = 53.4\ m$

At t = 10 s, t_{B-C} = 2 s

$\bar{d}_{10} = 55\ m + \frac{1}{2}(-3.125\ m/s^2)(2\ s)^2$

$= 55\ m - \underline{6.25\ m} = 48.75\ m$

At t = 11 s, t_{B-C} = 3 s

$\bar{d}_{11} = 55\ m + \frac{1}{2}(-3.125\ m/s^2)(3\ s)^2$

$= 55\ m -$ ______ = ______

At t = 12 s, t_{B-C} = 4 s

$\bar{d}_{12}$ = ______

At t = 13 s, t_{B-C} = 5 s

$\bar{d}_{13}$ = ______

At t = 14 s, t_{B-C} = 6 s

$\bar{d}_{14} = -1.25\ m$

At t = 15 s, t_{B-C} = 7 s

$\bar{d}_{15}$ = ______

At t = 16 s, t_{B-C} = 8 s

$\bar{d}_{16} = -45\ m$

From C to D

Between C and D, the velocity is constant at 25 m/s to the left for a period of 2 s, from t = 16 s to t = 18 s. The position during this interval is given by $\bar{d} = \bar{d}_{16} + \bar{v}\, t_{C-D}$

At t = 17 s, t_{C-D} = 1 s

$\bar{d}_{17} = -45\ m + (-25\ m/s)(1\ s)$

$= -45\ m - 25\ m =$ ______

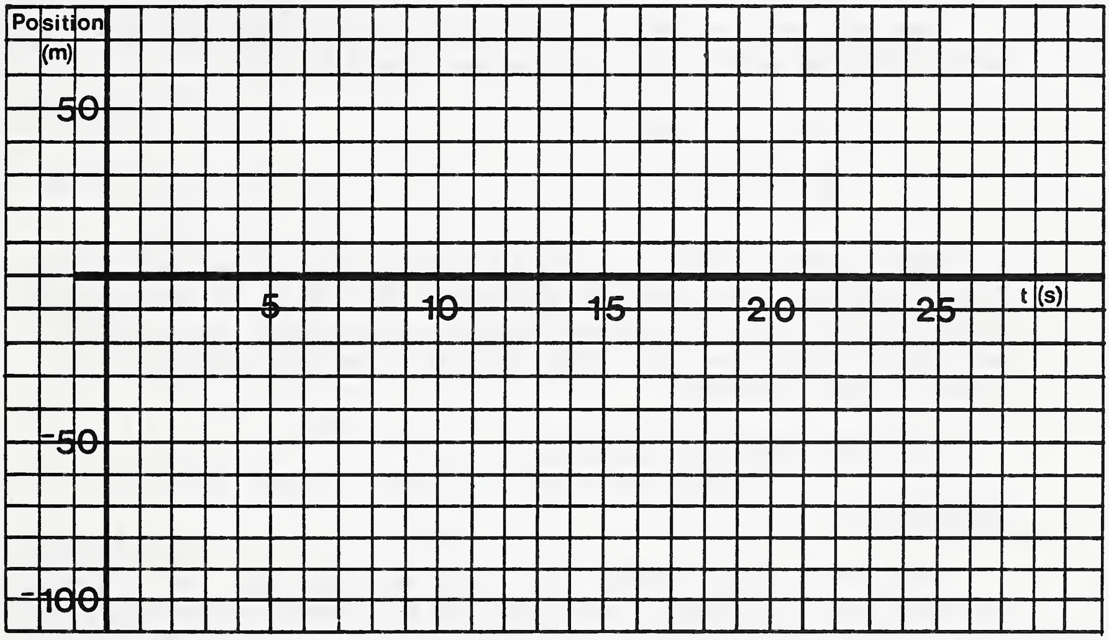
At t = 18 s, t_{C-D} = 2 s

$\bar{d}_{18} = -45\ m + (-25\ m/s)(2\ s)$

$= -45\ m - 50\ m =$ ______

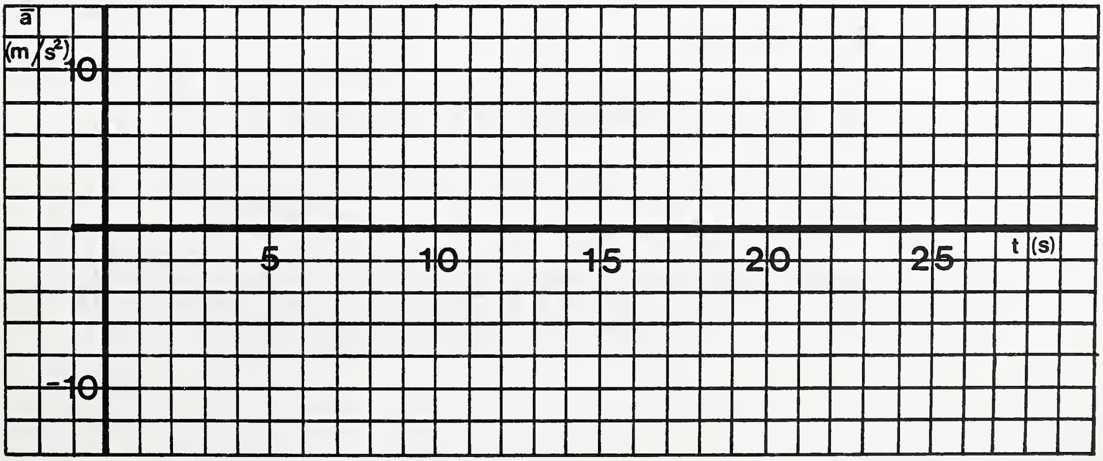
Using the results of the calculations on pages 9 and 10 complete the table below, and then plot the points on the graph, and draw the graph line through the points.

T(s)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
$\overline{d}$(m)																			



(c) Acceleration-time graph.

For the acceleration-time graph, note that there are only two periods of non-zero acceleration.



Algebraic Analysis

Read section 4.3 on pages 60 to 62 of the textbook.

If you are unsure about the use of the equations given in section 4.3, you should review Chapter 2 of the textbook, especially sections 2.8, 2.9, and 2.10, or see Lesson 3 of this course.

Note that the symbols in the equations could have been written with bars above the vector quantities rather than arrows.

$$\overline{d} = \overline{v_i}\, t + \tfrac{1}{2}\overline{a}\, t^2$$

$$\overline{v_f} = \overline{v_i} + \overline{a}\, t$$

The important thing to understand about these equations is that vector quantities are involved, and that this means that the direction must be accounted for when the equations are used. To do this, positive and negative signs must be used when the quantities are entered in the equations.

Study the following examples.

EXAMPLE 1

What is the final velocity of a body starting from rest and accelerating uniformly to the left at 15 m/s² for 5.0 s? What is the final speed?

Given: $\overline{v_i} = 0$

$\overline{a} = -15 \text{ m/s}^2$

$t = 5.0 \text{ s}$

To find: $\overline{v_f}$

Solution: $\overline{v_f} = \overline{v_i} + \overline{a}\, t$

$\overline{v_f} = 0 + (-15 \text{ m/s}^2)(5.0 \text{ s})$

$= -75 \text{ m/s}$

Speed $= v_f = 75 \text{ m/s}$

The final velocity is 75 m/s to the left. Final speed is 75 m/s (since speed is a scalar quantity, no direction is given for it).

EXAMPLE 2

What was the initial velocity of a body that was accelerated to the right at 8.00 m/s^2 for 3.50 s to a final velocity of 32.0 m/s to the right?

Given: $\overline{a} = +8.00\ m/s^2$

$t = 3.50\ s$

$\overline{v_f} = +32.0\ m/s$

To find: $\overline{v_i}$

Solution: $\overline{v_f} = \overline{v_i} + \overline{a}t$

$$\overline{v_i} = \overline{v_f} - \overline{a}t$$

$$= 32.0\ m/s - (8.00\ \frac{m}{s^2})(3.50\ s)$$

$$= 32.0\ m/s - 28.0\ m/s$$

$$= +4.0\ m/s$$

The initial velocity was 4.0 m/s to the right.

EXAMPLE 3

For the body described in Example 2, what would have been the displacement of the body after the 3.50 s of acceleration at 8.00 m/s^2?

Given: $\overline{v_i} = +4.0\ m/s$

$t = 3.50\ s$

$\overline{a} = +8.00\ m/s^2$

To find: $\overline{d}$

Solution: $\overline{d} = \overline{v_i}t + \frac{1}{2}\overline{a}t^2$

$$\overline{d} = (+4.0\ m/s)(3.50\ s) + \tfrac{1}{2}(+8.00\ m/s^2)(3.50\ s)^2$$

$$= +14\ m + 49\ m$$

$$= 63\ m$$

The displacement would have been 63 m to the right.

1. A body accelerates from rest for 15.0 s to a velocity of 75.0 m/s to the right. It remains at that velocity for 4.00 s, and then accelerates for 11.0 s to a velocity of 24.0 m/s to the left. Find the following things.

   (a) The acceleration during the first 15.0 s period.

   (b) The acceleration during the next 4.00 s period.

   (c) The acceleration during the final 11.0 s period.

(d) The displacement from the starting point to the end of the 11.0 s period. (It should include displacements in 15.0 s, 4.00 s and 11.0 s).

Lesson Summary

This lesson covered the following major topics.

1. Description of motion - a body may be described as being in motion with respect to an observer if a line joining the object to the observer changes in either length or direction.

   Motion must be considered as being definable only with respect to some specified point.

2. Vector and scalar quantities differ in that a vector quantity involves magnitude and direction while a scalar quantity involves only magnitude.

3. Both the magnitude and direction of motion can be described using position-time graphs, velocity-time graphs, and acceleration-time graphs.

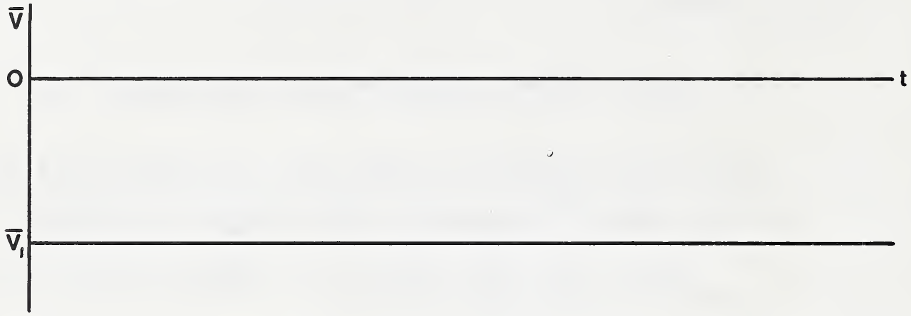
4. By using plus and minus signs for direction according to an accepted convention, the vector quantities of motion (displacement, velocity, and acceleration) can be used in the equations of motion. (Please read page 21 at this point)

Do the following questions.

QUESTIONS

1. Describe the motions indicated by the following graphs. Fill in the blanks in parts (a), (b) and (e). In parts (c) and (d), use brief sentences in your description.

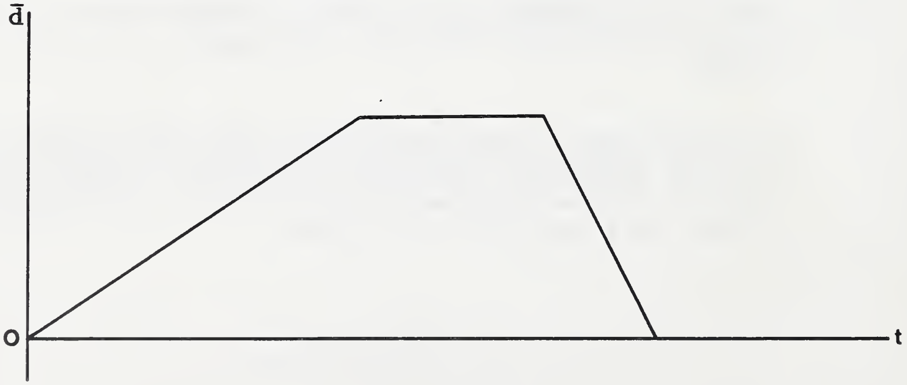
(a) VELOCITY-TIME GRAPH



The body has a ________________ velocity to the
(constant, varying)

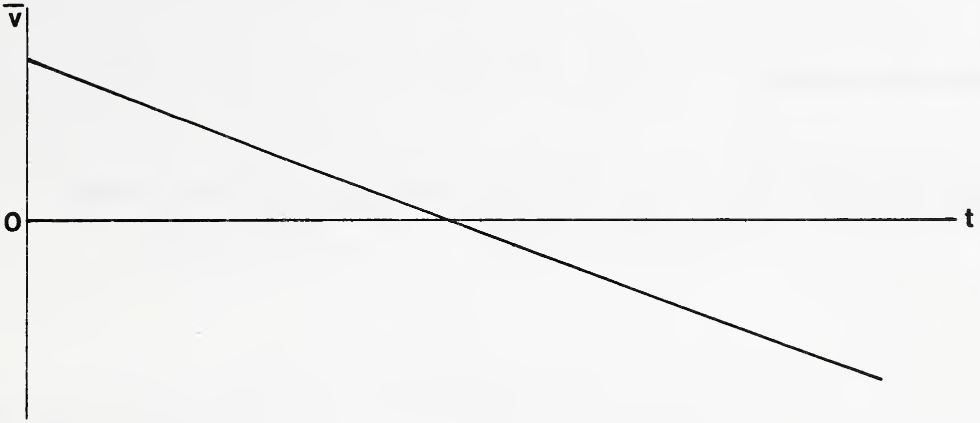
____
(right, left)

(b) DISTANCE-TIME GRAPH

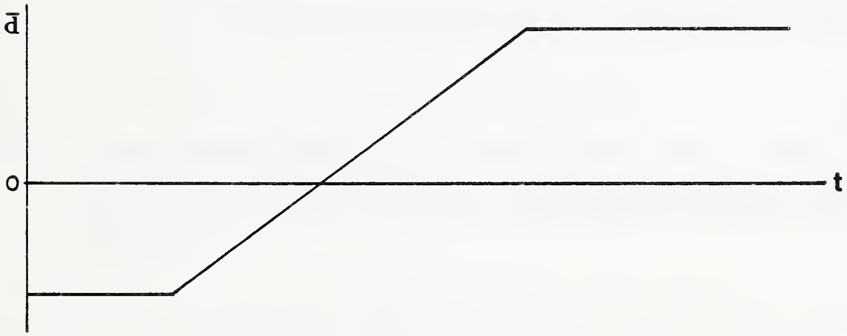


The body changes position uniformly up to a particular point. Then it remains stationary at that point for a while. The point is to the __________ of the origin. Then the body
(right, left)
moves uniformly back to the __________.

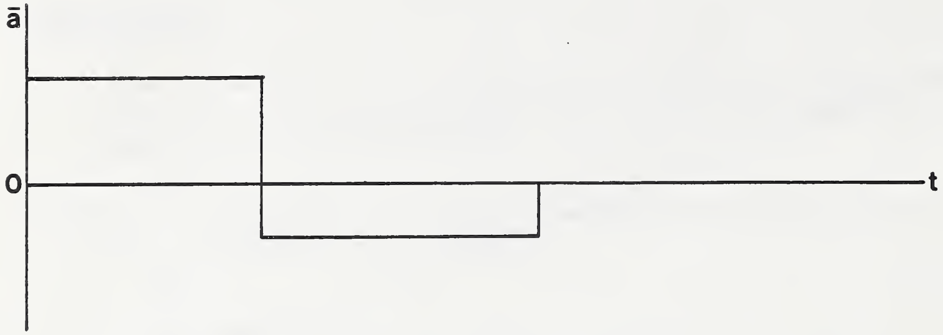
(c) VELOCITY-TIME GRAPH



(d) DISTANCE-TIME GRAPH



(e) ACCELERATION-TIME GRAPH



A body is at first undergoing a ______________________
positive, negative
uniform acceleration and then is uniformly accelerated in a

______________________ direction.
positive, negative

2. A baseball player hits a ball straight upward with an initial speed of 40 m/s. Assume that $\bar{a}_g = -9.8$ m/s^2 (downward), and answer the following questions.

   (a) What is the velocity of the ball after 2.0 s?

   (b) What is its velocity after 6.0 s?

(c) How many seconds after starting does the ball reach its highest point?

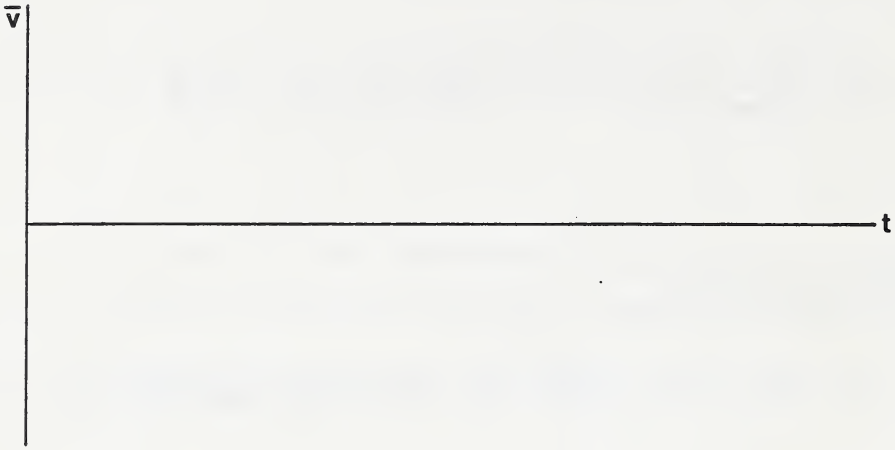
(d) What is the velocity of the ball after falling for 1.0 s from the highest point?

(e) What is its velocity just before it is caught by the catcher?

3. A ramp when sloped at a certain angle gives a ball a uniform acceleration of 5.0 m/s^2. If a ball is rolled up this ramp at an initial speed of 30 m/s, how far along the ramp will it roll before stopping?

4. A helicopter at a height of 50 m and rising upwards at 30 m/s releases an object. Assume that $\overline{a}_g = -9.8\ m/s^2$ (downward acceleration is negative).

(a) Sketch the velocity-time graph for the object's motion.



(b) Calculate the greatest height reached by the object. (Hint: Initial velocity of the object will be 30 m/s upwards.)

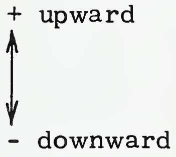
(c) How many seconds after the object is released from the helicopter will the object reach the ground? (Hint: It will move upwards till the velocity becomes zero and then it will come down to the earth. You have to find time for both separately and then add.)

Note - Direction Convention for Falling Objects and Weights

In this lesson and for the remainder of this course we will consider the upward direction as positive and the downward direction as negative. Thus the acceleration due to gravity is $-9.8\ m/s^2$ (negative because it acts downward). The weight of a body is negative - it also acts downward. The height of an object is positive because we usually measure height from the ground upward.

Please note that this is opposite the convention in the book which considers the upward direction negative and the downward direction positive.

Just remember that in these lessons upward is positive and downward is negative. Any answers that include velocity, displacement, weight, acceleration due to gravity should take this convention into account.



END OF LESSON 5

LESSON RECORD FORM

1260 Physics 10

Revised 89/02

FOR STUDENT USE ONLY

Date Lesson Submitted ____________________

Time Spent on Lesson ____________________

(If label is missing or incorrect)

File Number ____________________

Lesson Number ____________

Student's Questions and Comments

Apply Lesson Label Here

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Postal Code ____________________

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Additional Grading E/R/P Code: ________

Mark: ____________

Graded by: __________

Assignment Code: ______

Date Lesson Received: ____________________

Lesson Recorded ______

Teacher's Comments:

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Correspondence Teacher

St. Serv. 1-86

ALBERTA CORRESPONDENCE SCHOOL

MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS

1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

VECTORS AND VECTOR DIAGRAMS

Representing Vector Quantities

Study section 4.4 of the textbook on pages 62 and 63.

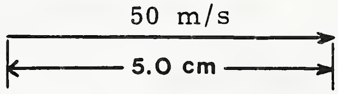
As indicated in the textbook, vector quantities can be represented by lines of certain lengths arranged in particular directions. The lengths of the lines represent the sizes or magnitudes of the vector quantities and the directions of the lines, as shown by arrowheads, represent the directions of the vector quantities.

In order to decide how long we should make a line, we must select a scale. This is illustrated in Fig. A. To represent a velocity of 50 m/s east, we must consider how much space we have on our paper and try to pick a scale that allows us to draw a line in the space that would conveniently represent 50 m/s. In Fig. A, a scale of 1.0 cm = 10 m/s was selected. We could have selected scales such as 1.0 m = 1.0 m/s, or 10 cm = 10 m/s, but if we did that, we would not have been able to draw the line in the space available on the paper. We could have picked a scale such as 1.0 cm = 50 m/s, or 1.0 mm = 10 m/s, but then we would have had a much shorter line, and we would not have used the space available as well as we could have. When a scale is to be selected it is best to pick one that will allow the use of most of the space available.

Fig. A

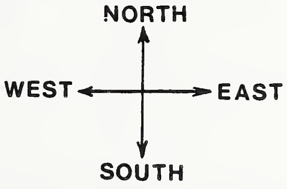
$\bar{v}$ = 50 m/s east

Scale: 1.0 cm = 10 m/s
Therefore, 50 m/s = 5.0 cm



In order to show the directions of vector quantities, it is useful to select some kind of reference that applies to many situations. For our purposes in this course, a useful reference is the directions cross which defines the compass points of north, south, east, and west as they are shown in Fig. B. Notice that north is toward the top of the page, south is toward the bottom, east is to the right of the page, and west is to the left of the page.

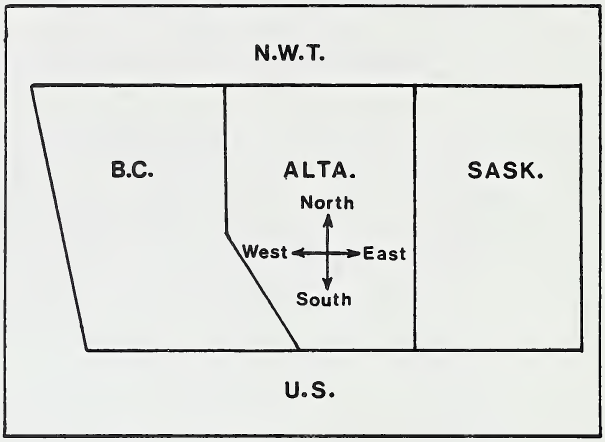
Fig. B



The correspondence between this convention and the directions on the earth's surface can be seen if you point the top of the page toward the north. Then (if you are familiar with the directions in your area) you will see that the bottom, right, and left sides of the page coincide with the directions of south, east, and west, respectively.

If you remember a little geography, and you are familiar with some maps, it is easy to check your memory of the direction convention. For example, if you live in Alberta, you should know that British Columbia is to the west, Saskatchewan is to the east, the United States is to the south, and the Northwest Territories is to the north. Also, you should be able to visualize a rough map showing this arrangement, as illustrated in Fig. C.

Fig. C

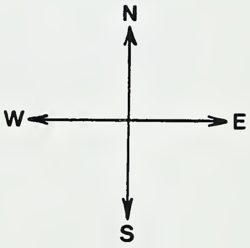


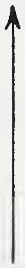
Do the following questions. Note that a cm ruler is required.

QUESTIONS

1. Using the scales indicated and the direction convention given in the preceding section of this lesson, find the magnitudes and directions of the vectors represented by the vector lines below.

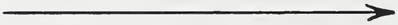
(a) Scale: 1 cm = 10 m





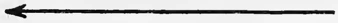
$\bar{d}$ = ____________

(b) Scale: 1 cm = 5 m/s



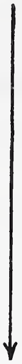
$\bar{v}$ = ____________

(c) Scale: 1 cm = 25 m



$\bar{d}$ = ______________

(d) Scale: 1 cm = 18 m/s



$\bar{v}$ = ______________

2. Using the scales given below and the direction convention given in the preceding section of this lesson, draw lines to represent the following vector quantities.

(a) 60 m south
Scale: 1 cm = 12 m

(d) 150 m/s north
Scale: 1 cm = 25 m/s

(b) 280 m/s west
Scale: 1 cm = 70 m/s

(c) 18 m west
Scale: 1 cm = 2 m

3. Select appropriate scales, and draw lines representing the following vector quantities.

   (a) 600 m/s south

   (b) 28 m east

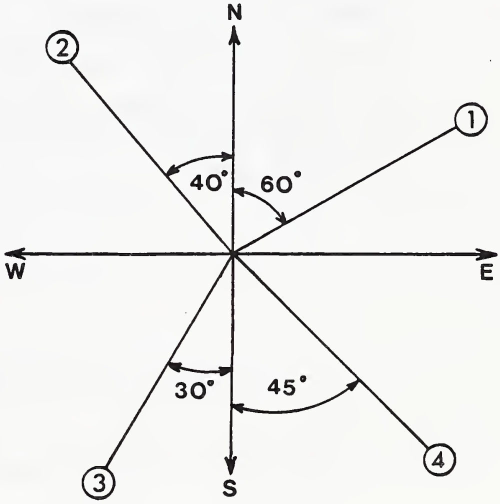
   (c) 120 m west

More on Direction

So far in this lesson, the directions of the vector lines have been parallel to the north-south and east-west lines of the directions cross. However, as you probably know, vector quantities might have directions that are not parallel to those lines. In order to indicate such directions, it is necessary to make measurements of angles. To do this, a protractor should be used. (If you do not have a protractor now, you should obtain one before you continue with this lesson.)

As with making measurements of length, to measure angles it is useful to have a convenient starting point or reference point. Actually, to make measurements of angles on a surface, not only a reference point is needed, but also a reference line is needed from which to make measurements. In Fig. D, several measurements of angles have been made. Both a reference point and a reference line are involved in those measurements. The reference point is the point at which the N-S and E-W lines of the directions cross intersect or cross each other. The reference line is the N-S line from which the angles are indicated. Note that each of the lines drawn at an angle (other than 90°) to the N-S line is numbered ①, ②, ③, ④ . In order to make clear the directions of the numbered lines, both the angle and its direction of measurement from the N-S line must be specified, as indicated below.

Fig. D



① 60° east of north
② 40° west of north
③ 30° west of south
④ 45° east of south

Note the following things.

1. A line sloping above the E-W line, and to the right of the N-S line is east of north.
2. A line sloping above the E-W line and to the left of the N-S line is west of north.
3. A line sloping below the E-W line and to the left of the N-S line is west of south.
4. A line sloping below the E-W line and to the right of the N-S line is east of south.

Thus, for the lines drawn on a piece of paper, upward sloping lines are associated with north, and downward sloping lines are associated with south. Also, left and right are associated with west and east, respectively.

If you are not clear on how to use a protractor to make the measurements of angles such as those in Fig. D, study the following notes and figures before you go on to do the next set of exercises.

A protractor is illustrated in Fig. E. It is positioned so that the 180° line lies over the N-S line, and the 90° line lies over the E-W line, with the 90° line toward the right side of the page. When this is done, the directions of 60° east of north and 45° east of south can be easily read from the protractor. Take your protractor and place it in the same position as shown in Fig. E, and you will be able to see how the angles can be measured. Notice that the direction of a line toward the east is either 90° east of north, or 90° east of south, but that the direction should be specified simply as being east.

Fig. E

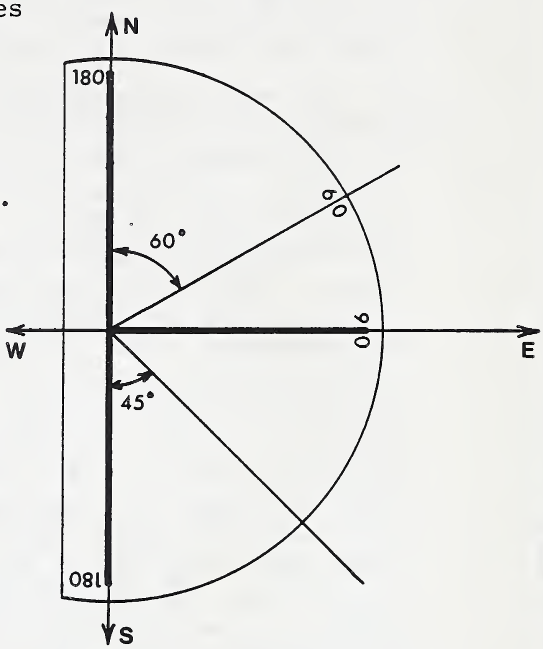
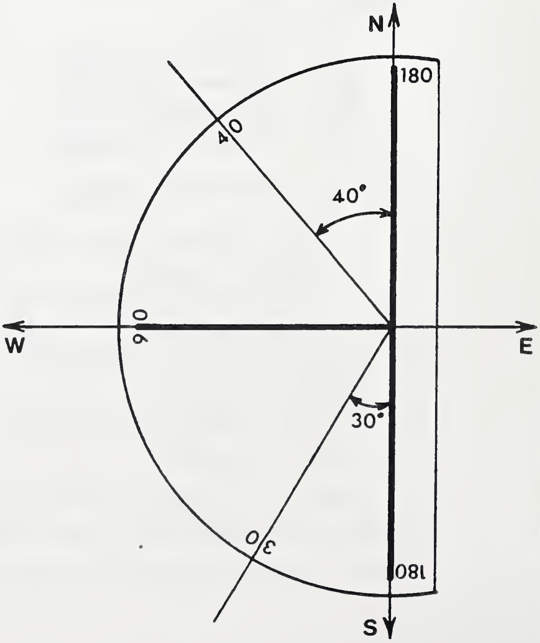


Fig. F

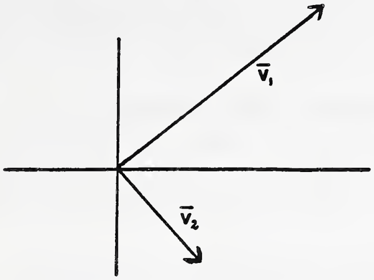


In Fig. F, a protractor is illustrated positioned so that it can measure angles west of the N-S line. The 180° line of the protractor lies over the N-S line and the 90° line lies over the E-W line and pointed to the left. If you position your protractor in a similar way, you will be able to see how the angles of 40° west of north and 30° west of south can be measured. Also, notice that the direction of a line toward the west is either 90° west of north or 90° west of south, but that the direction should be specified as being west.

QUESTIONS

1. Give the magnitudes and directions of the vector quantities represented in the following diagrams.

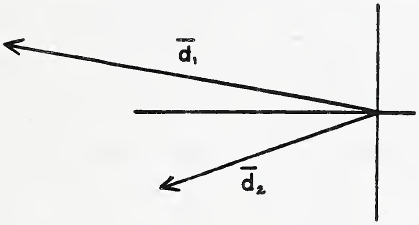
(a) Scale: 1 cm = 25 m/s



$\overline{v}_1$ = ______________________

$\overline{v}_2$ = ______________________

(b) Scale: 1 cm = 40 m



$\overline{d}_1$ = ______________________

$\overline{d}_2$ = ______________________

2. Draw lines representing the following vector quantities.

(a) 250 m 75° east of north
Scale: 1 cm = 50 m

(b) 8.0 m/s 65° west of north
Scale: 1 cm = 1.0 m/s

(c) 750 m/s 30° west of south
Scale: 1 cm = 75 m/s

(d) 20 m 15° east of south
Scale: 1 cm = 5.0 m

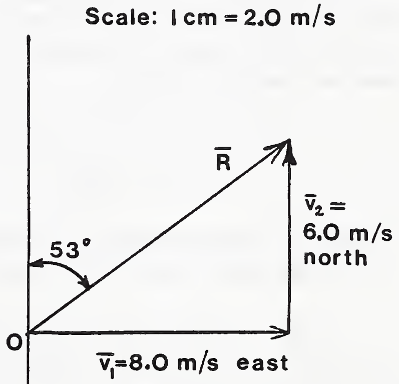
Vector Diagrams 1

As shown in the textbook, vectors can be used to solve certain kinds of problems. One way of doing this is to use vector diagrams in which vector lines are drawn using the same scale and correct directions, and are combined to obtain a resultant. In physics, the term resultant often is used to name the vector quantity that results when vectors are combined.

The simplest vector diagram involves two vector lines which are joined together, and a resultant vector line giving the result of the combination. Fig. G shows how a vector diagram would be used to solve the following problem.

What is the resultant velocity of 8.0 m/s east, and 6.0 m/s north? To solve this problem, a suitable scale is selected first. Then, a line representing 8.0 m/s east is drawn. From the arrowhead end of this line, the line representing 6.0 m/s north is drawn. To draw the resultant, start at the beginning of the first vector line (point 0) and draw a line to the arrowhead of the second vector line. Measurements of the length of the resultant line and the angle between it and the N-S line at 0 give the magnitude and direction of the resultant respectively. This procedure is summarized below.

Fig. G



$\bar{R}$ is 5 cm long, so it represents 10 m/s
$\bar{R}$ = 10 m/s 53° east of north

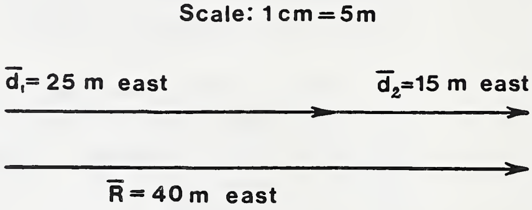
1. Select an appropriate scale.
2. Draw the first vector line to scale and in the correct direction from the starting point, 0.
3. Draw the second vector line to the same scale and in the correct direction, starting from the tip of the arrowhead of the first vector line.
4. Draw the resultant vector line from the starting point, 0, to the tip of the arrowhead of the second vector line.
5. Measure the length of the resultant line to find the magnitude of the resultant, and the angle between it and the N-S line at 0 to determine the direction of the resultant.

Note that an arrowhead should be included at the end of each vector line in order to clearly show the direction of the vector line.

There are two cases in which the procedure described above cannot be followed exactly. These two cases are: (1) when the two vectors are in the same direction; and (2) when the two vectors are in opposite directions. However, it is possible to draw vector diagrams in these two cases, as illustrated in the following notes.

What is the resultant of displacements of 25 m east and 15 m east?

Fig. H


Scale: 1 cm = 5 m
$\overline{d_1}$ = 25 m east
$\overline{d_2}$ = 15 m east
$\overline{R}$ = 40 m east

The method of solving this using a vector diagram is shown in Fig. H. However, it is simpler to not bother with drawing a vector diagram. Since the vector quantities are in the same direction, it is easier to add them:

$$\overline{R} = \overline{d_1} + \overline{d_2} = 25 \text{ m east} + 15 \text{ m east}$$
$$= 40 \text{ m east}$$

What is the resultant of displacements of 25 m east and 15 m west?

Fig. I

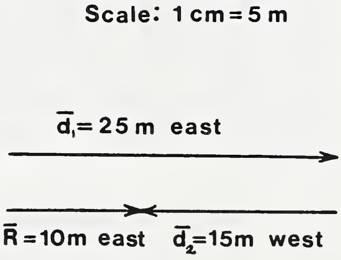

Scale: 1 cm = 5 m
$\overline{d_1}$ = 25 m east
$\overline{R}$ = 10m east
$\overline{d_2}$ = 15m west

Fig. I shows the method of solving this problem using a vector diagram. However, often it is simpler not to draw the vector diagram. Since the vector quantities are in opposite directions, it is easier to assign a minus sign to one direction (west), and a plus sign to the opposite direction (east):

$$\overline{R} = \overline{d_1} + \overline{d_2} = 25 \text{ m east} + 15 \text{ m west}$$
$$= +25 \text{ m} + (-15 \text{ m})$$
$$= +10 \text{ m}$$
$$= 10 \text{ m east.}$$

Do the following exercises using vector diagrams.

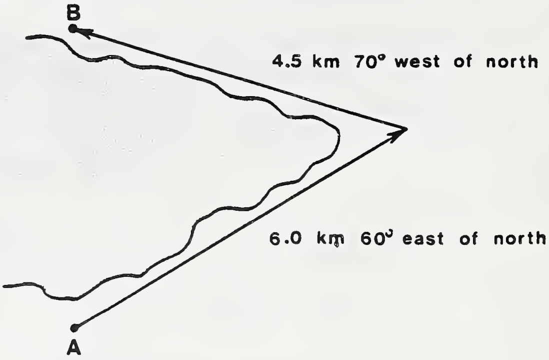
QUESTIONS

1. A car travels 200 km west and then 150 km south. Find the resultant displacement.

The resultant displacement is ____.

2. An aircraft with a velocity of 400 km/h east meets a wind having a velocity of 80 km/h north. Find the resultant velocity of the aircraft. (Assume that the effect of the wind's velocity would be fully transferred to the aircraft.)

3. A fisherman is near one end of a lake at point A, and he wishes to get from A to point B on the other side. See the diagram. What would be his displacement if he travelled from A to B? Note that the lines drawn in the diagram are not to any particular scale.



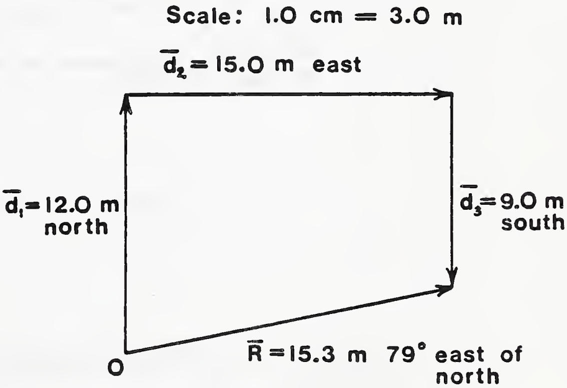
Vector Diagrams 2

In the preceding section, we examined the method of drawing vector diagrams when two vector quantities are involved initially, and a resultant is to be found. Often, this method is good enough to solve problems involving vector quantities. However, sometimes more than two vector quantities are involved initially, and it is necessary to find a resultant. To do this using a vector diagram we can use basically the same procedure as before, as illustrated in Fig. J.

The problem is: What is the resultant of displacements of 12.0 m north, 15.0 m east, and 9.0 m south?

As before, a scale must be selected, and the vector lines are drawn according to the scale and in the directions specified. Note that $\overline{d_1}$ begins at 0, $\overline{d_2}$ begins at the tip of the arrowhead of $\overline{d_1}$, and $\overline{d_3}$ begins at the tip of the arrowhead of $\overline{d_2}$. The resultant is drawn from 0 to the tip of the arrowhead of $\overline{d_3}$. The only difference between this method and the one given earlier is that $\overline{d_3}$ is included, and the resultant must be drawn to the tip of the arrowhead of $\overline{d_3}$. This method can be used with any number of vector lines, from two up. Fig. K and L show the use of this method to solve multivector problems.

Fig. J

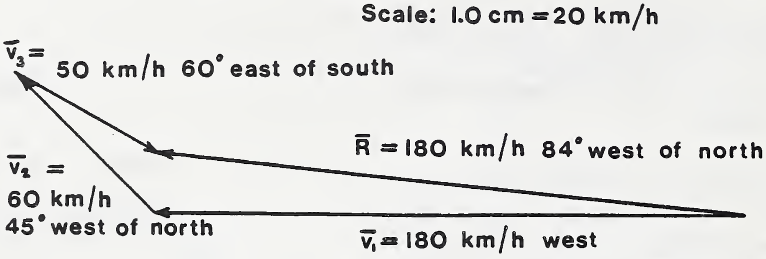

Scale: 1.0 cm = 3.0 m
$\overline{d_2}$ = 15.0 m east
$\overline{d_1}$ = 12.0 m north
$\overline{d_3}$ = 9.0 m south
O
$\vec{R}$ = 15.3 m 79° east of north

Resultant is 15.3 m 79° east of north.

A search and rescue aircraft is flying low through mountain valleys and passes. At one point in a gap between several valleys, it has a velocity of 180 km/h west and is acted upon by two winds blowing down two different valleys. One wind has a velocity of 60 km/h 45° west of north, and the other has a velocity of 50 km/h 60° east of south. What is the resultant of these velocities?

The method of doing this is shown in Fig. K.

Fig. K

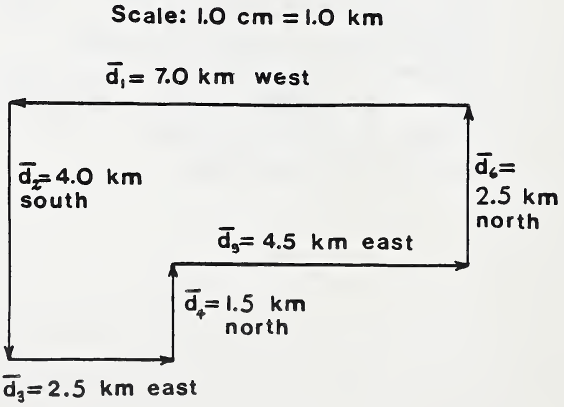

Scale: 1.0 cm = 20 km/h
$\bar{v}_3$ = 50 km/h 60° east of south
$\bar{R}$ = 180 km/h 84° west of north
$\bar{v}_2$ = 60 km/h 45° west of north
$\bar{v}_1$ = 180 km/h west

Resultant velocity is 180 km/h 84° west of north.

Find the resultant displacement of the following displacements: 7.0 km west, 4.0 km south, 2.5 km east, 1.5 km north, 4.5 km east, 2.5 km north. The method of doing this is shown in Fig. L.

Note that six vector lines are involved in the diagram shown in Fig. L. Also, note that when all six of the lines have been drawn, the last vector line ends at the original starting point. This means that no resultant line needs to be drawn, or that the resultant is equal to zero.

Fig. L


Scale: 1.0 cm = 1.0 km
$\bar{d}_1$ = 7.0 km west
$\bar{d}_2$ = 4.0 km south
$\bar{d}_6$ = 2.5 km north
$\bar{d}_5$ = 4.5 km east
$\bar{d}_4$ = 1.5 km north
$\bar{d}_3$ = 2.5 km east

Since no resultant vector line needs to be drawn the resultant displacement is zero.

Do the following exercises.

QUESTIONS

1. Find the resultant of 30 km/h north, 40 km/h 45° west of north and 70 km/h 65° east of south.

2. A man walks from point 0 as follows: 10.0 km 15° west of north, then 20.0 km 75° west of south, then 15.0 km east, and then 5.0 km south to reach point A. Find the following:

   (a) His resultant displacement with respect to 0. Use the scale of 1 cm = 2 km.

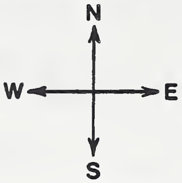
   ∘ Point 0

   (b) His displacement from A if he wished to have a resultant displacement of zero with respect to point 0.

Lesson Summary

This lesson covered the following major topics.

1. Vector quantities may be represented by lines drawn to scale in the appropriate directions, according to an accepted convention.



2. Directions may be conveniently specified using angles measured from the N-S line using a protractor.

3. To find the resultant of two or more vector lines, the vector lines should be drawn with the first vector line starting at a point, such as 0, and the next vector line beginning at the tip of the arrowhead of the first vector line. Then, other vector lines may be drawn from the tips of the arrowheads of preceding vector lines until all given vector lines have been drawn. The resultant vector line then may be drawn from the starting point, 0, to the tip of the arrowhead of the last given vector line.

Do the following questions.

QUESTIONS

1. In still air, a bumble bee flies with a speed of 0.5 m/s. If a wind with a velocity of 1.0 m/s north appears when the bumble bee is flying, find the following.

   (a) The bee's velocity if he flies south.

   ____

   (b) The bee's velocity if he flies north.

   ____

   (c) The bee's velocity if he flies east. Draw a vector diagram to solve this part.

2. An ant sets out on a journey on a floor. He or she (sex uncertain) travels 20 cm south, 5 cm east, 30 cm north, 15 cm west, and 5 cm south. What is his or her or its displacement from the starting point? Draw a vector diagram to solve this question.

End of Lesson 6

LESSON RECORD FORM

1260 Physics 10

Revised 89/02

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Time Spent on Lesson ____________________

(If label is missing or incorrect)

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1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:

(1) All pages are numbered and in order, and no paper clips or staples are used.
(2) All exercises are completed. If not, explain why.
(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
(4) The Lesson Record Form is filled out and the correct lesson label is attached.
(5) This mailing sheet is placed on the lesson.

2. POSTAGE REGULATIONS

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

3. POSTAGE RATES

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Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a **green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.**

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

FORCE, INERTIA AND MASS

The Explanation of Motion

Read section 5.1 on pages 69 to 71 of the textbook.

As noted in the textbook, in our study of motion so far, we have been concerned with kinematics, which deals with the description of motion. To explain why motion occurs, we must study the area of physics known as dynamics. This approach to the study of motion, starting with a description of what is happening, and then trying to explain why it has happened, is a useful approach in other areas besides the physics of motion. Usually, it is necessary to know what really occurred before trying to explain it, especially if you are trying to solve a problem.

A useful explanation is one that not only is consistent with a particular law, but also one that can be used to predict what will happen in a particular situation. An explanation which is logically consistent with a law is not very useful if it does not provide a way of making predictions which can be checked or tested. Thus, for an explanation to be satisfactory scientifically, it must involve the following three features:

(1) It must be logically consistent with certain laws or rules.

(2) It must provide a way of making predictions.

(3) The predictions that are derived from it must be testable, and once tested must be accurate.

QUESTIONS

1. What is the difference between kinematics and dynamics?

____

____

____

2. Of the following concepts which three are concepts of kinematics? Position, mass, speed, force, momentum, displacement.

(a) ______________________________

(b) ______________________________

(c) ______________________________

3. Why is it a good idea to have a satisfactory description of what happened before you try to explain why it happened?

It is hard to explain the causes of an event, unless the event is carefully observed, and described in detail.

4. For a scientific explanation to be satisfactory, what features should it have?

____

____

____

____

____

____

____

____

____

____

Familiar Forces and Units of Force

An important concept in the area of dynamics is the idea of force. A force that most people are familiar with is the force of weight. We can feel our own weights, especially if we do something that requires that we lift ourselves – such as exercises like chin ups, push ups or sit ups. We can feel the weight of other things when we try to lift them. Another force that people experience is the force of friction. Friction forces act between two surfaces which are in contact with each other and they tend to act against the motion of one surface with respect to the other. If there is a large friction force, it may be very difficult to move something. For example, it might be much more difficult to slide a desk across a carpeted floor than across a smooth tiled floor because the friction force between the carpet and the desk is much larger. On the other hand, very small friction forces might cause difficulties also, as in the case of walking across smooth ice.

In this course, most of the forces will be expressed in one unit, called the newton (after Sir Isaac Newton). N is the symbol for the newton. We will give a more formal definition of the newton in a later lesson, but to get a feeling for what a newton involves, consider the following.

Weight of two golf balls is about 1 N.

Weight of a flashlight battery (a D cell) is about 1 N.

Weight of a softball is about 2 N.

Weight of a two litre carton of milk is about 20 N.

Forces as Vector Quantities

Read sections 5.2, 5.3 and 5.4 on pages 71 to 76 of the textbook.

The idea of force as simply a push or a pull exerted on an object is an easy one to understand, since it is so closely related to everyday experience. In order to move around throughout each day, a person must exert forces on a number of different objects. For example, if a person walks out of a house, he or she must exert forces on the floor through legs and feet as well as exerting forces through arms and hands on the door in order to open and close it. It is clear that the direction as well as the size of each force exerted is important. Inside a house, if you turn the doorknob and push on an inward-opening door, you won't open it; such a door must be pulled in order to be opened. This illustrates the necessity of considering forces as vector quantities.

We can deal with forces as vector quantities by using the same kinds of methods as we used earlier; that is, we can use lines with arrowheads to represent forces, and we can use vector diagrams to solve certain kinds of problems involving forces. Since the preceding lesson was concerned with representing vector quantities and drawing vector lines, you should be familiar with the methods of doing this. However, if you are not clear about some of the methods used, you should review the preceding lesson before continuing with this lesson.

The simplest situation in which two forces are involved (when it is necessary to find a resultant) occurs when the two forces act along the same straight line in the same direction. Such a problem can be solved using a vector diagram, but usually it is easier to simply add the sizes of the two forces to obtain the size of the resultant, and indicate its direction as being the same as the direction of the original forces.

What is the resultant of forces of 20 N east and 16 N east?

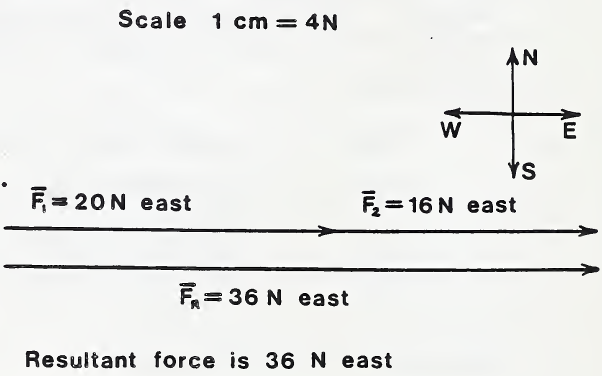
A vector diagram solving this problem is shown in Fig. A. Below, the problem is solved without the use of a vector diagram.

$$\overline{F_R} = \overline{F_1} + \overline{F_2}$$

$$\overline{F_R} = 20\text{ N east} + 16\text{ N east}$$

$$\overline{F_R} = 36\text{ N east}$$

Fig. A


Scale 1 cm = 4N
N
W
E
S
$\overline{F_1}$ = 20 N east
$\overline{F_2}$ = 16 N east
$\overline{F_R}$ = 36 N east
Resultant force is 36 N east

Another simple situation involves two forces which act along the same straight line, but in opposite directions. As before, a vector diagram may be used to find the resultant, but it may be easier to make the force in one direction positive, and the force in the opposite direction negative. Then, they can be combined to find the resultant.

What is the resultant of forces of 20 N east, and 16 N west?

A vector diagram solving this problem is shown in Fig. B. Below, the problem is solved without the use of a vector diagram.

Make east positive, and west negative.

$$\overline{F}_R = \overline{F}_1 + \overline{F}_2$$

$$\overline{F}_R = 20 \text{ N east} + 16 \text{ N west}$$

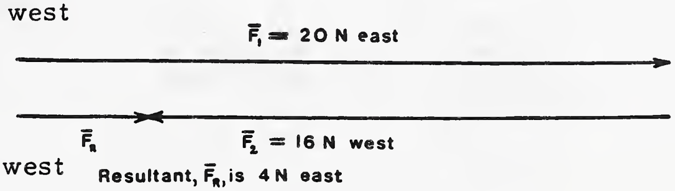
$$\overline{F}_R = +20 \text{ N} + (-16 \text{ N})$$

$$\overline{F}_R = +4 \text{ N} = 4 \text{ N east}$$

Resultant force is 4 N east.

Fig. B

Scale: 1 cm = 2 N



Resultant, $\overline{F}_R$, is 4 N east

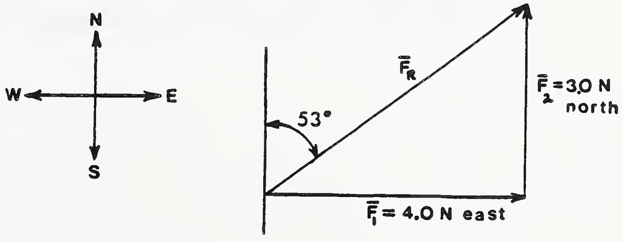
Of course, forces do not always act along the same straight line, and to find the resultant in such cases it is useful to draw vector diagrams according to the rules given in the preceding lesson. The following examples show the application of those rules to problems involving forces.

Find the resultant of two forces, one 4.0 N east, and the other 3.0 N north.

The solution is shown in Fig. C.

Fig. C

Scale: 1 cm = 1.0 N



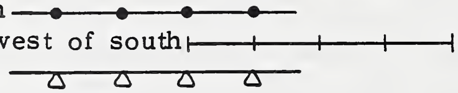
Resultant, $\overline{F}_R$, is 5.0 N 53° east of north.

Find the resultant of the following set of forces:

8.0 N north

5.0 N 45° west of south

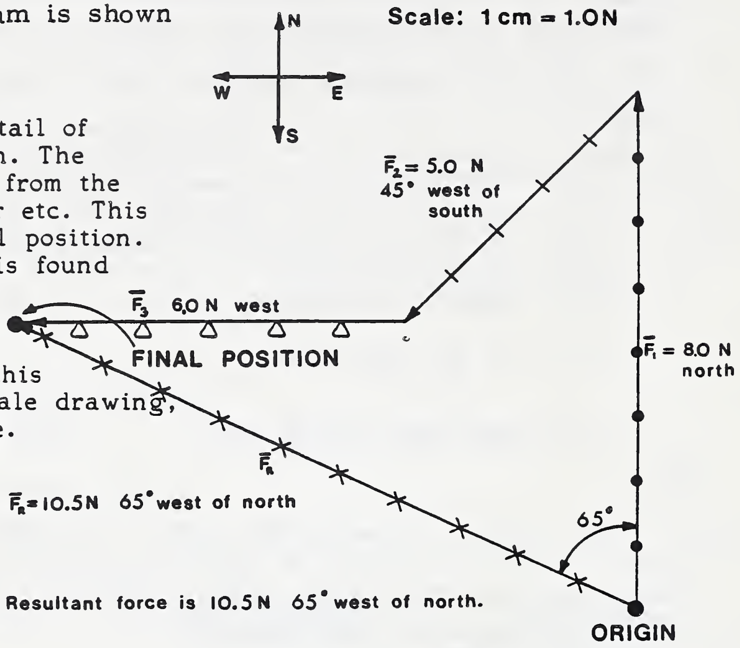
6.0 N west



The vector diagram is shown in Fig. D.

The origin is at the tail of the first vector drawn. The next vector is drawn from the tip of the first vector etc. This brings us to the final position. The resultant vector is found by joining the origin and the final position. Measure the angle and length of this vector, F_R, in the scale drawing, to determine its value.

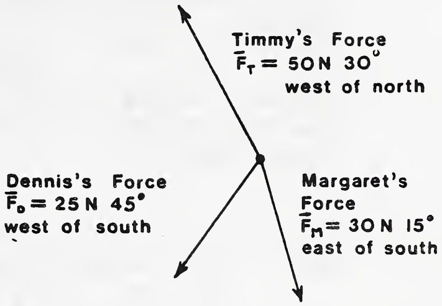
Fig. D


N
W
E
S
Scale: 1 cm = 1.0N
$\overline{F}_2$ = 5.0 N 45° west of south
$\overline{F}_3$ 6.0 N west
FINAL POSITION
$\overline{F}_1$ = 8.0 N north
$\overline{F}_R$
$\overline{F}_R$ = 10.5N 65° west of north
65°
Resultant force is 10.5N 65° west of north.
ORIGIN

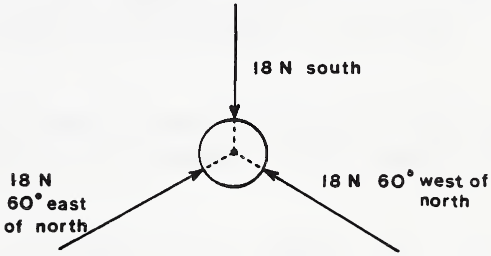
QUESTIONS

1. Two children have a dispute over a toy. Dennis pulls with a force of 25 N, and Margaret pulls in the opposite direction with a force of 30 N. What is the resultant force on the toy?

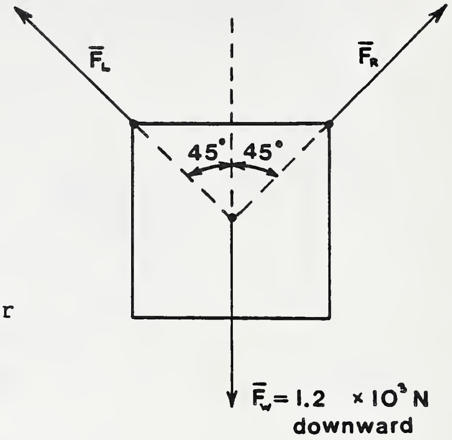
2. While Dennis and Margaret are struggling, a larger child, Timmy, arrives on the scene and decides to join in. This changes the arrangement of the forces applied to the toy, as shown in the diagram. Using a vector diagram, find the resultant force on the toy.


Timmy's Force
$\vec{F}_T = 50\text{ N}\ 30°$ west of north
Dennis's Force
$\vec{F}_D = 25\text{ N}\ 45°$ west of south
Margaret's Force
$\vec{F}_M = 30\text{ N}\ 15°$ east of south

3. Three forces act on a spherical object as illustrated in the following diagram. Find the resultant of these forces using a vector diagram.



4. A square sheet of metal weighing 1.2×10^3 N is to be supported by two cables, as shown in the diagram. The forces in the two cables, F_L and F_R, are to be equal in size. Using a vector diagram, find the size of each of the forces in the cable.



Hint: Your vector diagram should be like a right-angled isosceles triangle with $\bar{F}_w$ forming the hypotenuse. You should also see that $\bar{F}_L$ and $\bar{F}_R$ are each greater than 600 N.

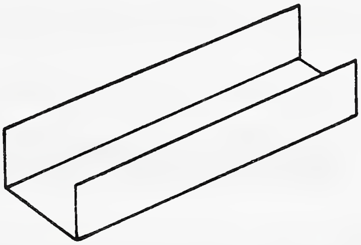
Newton's First Law of Motion

Read section 5.5 on pages 76 to 78 of the textbook.

EXPERIMENT #5 Some Effects of Inertia

AIM: To examine inertia through some of its effects.

APPARATUS:
- a marble
- a piece of paper, about 10 cm by 5 cm, folded to form a channel, as illustrated below.

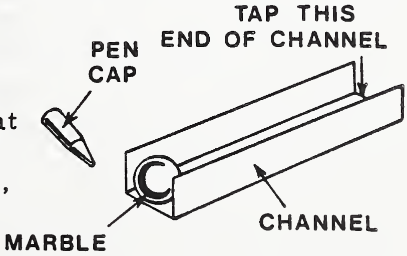


The channel should be large enough so that the marble can roll through it easily.

- a pencil or pen about 15 cm long.
- a marker such as a short pencil or the cap of a pen that can be placed near to the channel in order to mark its position.

PROCEDURE 1: The first step is to obtain a piece of paper of the right size, and fold it to form the channel. The channel width should be about 2 cm.

Arrange the items as shown in the diagram on a smooth surface such as a table or desk top. Using a long pencil or pen, tap the end of the channel sharply. A quick flick of the wrist should swing the pen or pencil just enough to give the channel the necessary tap. Using the pen cap as a marker, observe what happens to the channel and the marble. Try it several times, or until you are clear about what is happening.



OBSERVATIONS 1:

1. With respect to the marker, what happened to the channel when it was tapped?

___

___

2. With respect to the marker, what happened to the marble when the channel was tapped?

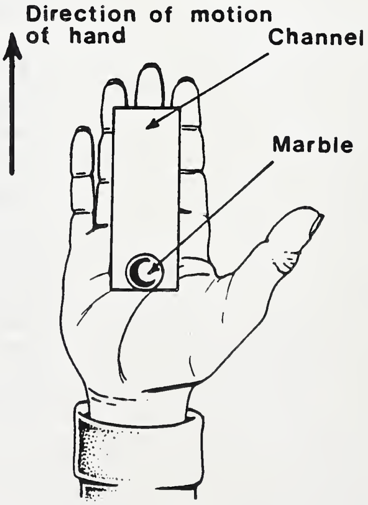
___

___

ANALYSIS 1: Give the differences in the motions of the channel and marble when the channel was tapped. Fill in the blanks.

Relatively high inertia of the ________ tends to keep it motionless. Lower inertia of the ________ allows it to be accelerated past the marker.

PROCEDURE 2: Pick up the channel and place it and the marble in the palm of your hand, as illustrated in the diagram. Move your hand forward at a steady rate, and then stop the motion of your hand suddenly. Observe what happens to the channel and the marble as your hand moves, and then suddenly stops. Try it several times, or until you are clear about what is happening.



OBSERVATIONS 2:

1. With respect to your hand, what happened to the channel as you moved your hand, and then suddenly stopped it?

____

____

2. With respect to your hand, what happened to the marble as you moved your hand, and then suddenly stopped it?

____

____

ANALYSIS 2: Give an explanation of the differences in the motions of the channel and the marble when your hand suddenly stopped.

The channel was held against the hand by frictional forces.

The inertia of the marble tended to keep it moving when the hand's motion stopped.

CONCLUSIONS: Indicate what role inertia played in the motions of the channel and marble in this experiment by filling in the blanks.

The ______________ had the higher mass. Therefore it had the higher inertia and its velocity is more difficult to change.

As indicated in the textbook, Newton's first law of motion, or the law of inertia, may be stated as follows:

> Every object continues in a state of rest or of uniform motion in a straight line unless acted upon by an external unbalanced force.

From this law, a definition of inertia can be derived. One form of the definition of inertia is that inertia is the tendency of a body to remain at rest or to continue moving uniformly in a straight line. In Experiment 5, the aim was to show some of the effects of this tendency called inertia.

Re-read Newton's first law of motion, and notice that the idea of force as well as inertia is involved in the statement of the law. Specifically, the reference is to an unbalanced force. What is meant by the term "unbalanced force?" We can answer this question by recalling that when we drew vector diagrams, we sometimes obtained resultants of zero. When the vectors involved in the diagrams were forces, this meant that when the forces were combined, they all balanced each other. Thus, for balanced forces, the resultant is zero. For unbalanced forces, the resultant force is not equal to zero. Often, the term "unbalanced force" refers specifically to the non-zero resultant of several forces acting on a body.

QUESTIONS

1. Compare the Newtonian and Aristotelian explanations of motion at constant velocity by answering the following:

   (a) Who said that a force must be applied continually to maintain a constant velocity? ________________

   (b) Who said that a force need only be applied to change the velocity of an object? ________________

2. What is inertia?

3. List another example of inertia shown by the following:

   (a) stationary bodies

   - When a glass of milk standing on a table is suddenly pulled towards you, some of the milk spills.

   (b) moving bodies

   - If the train you are riding stops suddenly while you are holding a glass of lemonade, some of the beverage may spill.

4. (a) What is meant by the phrase "balanced forces?"

   (b) What is meant by the phrase "unbalanced forces?"

5. Two men must push a stalled car to the side of a road. They find that it is quite difficult to get the car to move at first, but that once it is moving it is much easier to push the car. Why is the car easier to push once it is in motion?

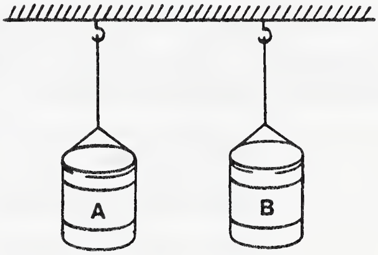
6. From what you know about inertia, does the use of seat belts in moving vehicles make sense? Give an explanation for your answer.

Inertia and Mass

Read sections 5.6 and 5.7 on pages 78 to 80 of the textbook.

When they are first met, the ideas of inertia and mass often do not seem to be very clear. Sometimes, this is especially true for the idea of mass. The statement in the textbook that mass was once considered to be a way of representing the amount of matter in a body seems to be clearer. After all, it usually seems to be true that when a body appears to have more matter in it – that is, it looks bigger – it is more "massive." However, one problem with looking at mass in this way is that it may lead to some confusion. This is because what is being done is that volume is being used as a guide for estimating mass. Volume is a direct indication of the size of a body; that is, it is a way of measuring how much space a body takes up. However, estimating volume is not a reliable way of determining how much matter is in a body. To understand this, we can do a simple thought experiment.

Fig. E



Suppose that there are two identical cans suspended from the ceiling by strings. Refer to Fig. E. The tin cans have covers on their tops and are labelled with the letters A and B. One can is empty, and the other can is full of concrete. By just looking at the cans, can you tell which one is empty and which one is full of concrete? Unless you have X-ray vision, you probably will not know which is which. How can you find out?

Probably, the easiest way to do this is to give each can a light push with your hand. You will be able to feel the difference in the resistance to the force applied by your hand. If can B is much harder to start moving than can A, you will know that can B is full of the concrete while **A** is the empty one.

This thought experiment illustrates some important things. It shows that a judgement about masses of bodies cannot be done reliably only on the basis of volume. Also, it shows that we can find out about the masses of bodies by applying forces to the bodies, and observing how these forces affect the motions of the bodies. In other words, it shows that inertia and mass are closely related.

The relationship of mass and inertia is given in the textbook by the following statement:

> mass is a measure of the inertia of a body.

Using the above statement and the method described in our thought experiment, we can provide a further definition. This definition is provided below.

> It is possible to determine which of two masses is greater by applying equal forces to each mass for equal time periods and observing which mass speeds up less. That mass is the greater one.

The above statement is a more detailed way of saying that mass is the measure of the inertia of a body. It is what is sometimes called an operational definition. An operational definition is a statement which describes an activity in order to explain the meaning of a word. Operational definitions are very important in physics and other sciences because they provide procedures which make clear how you can test for the presence of a phenomenon.

In making measurements of mass, the unit which is used often is the kilogram. Approximate masses of some objects with which you may be familiar are given below. Note that kg is the symbol for kilogram.

Mass of two golf balls is about 0.1 kg.

Mass of a flashlight cell (D cell) is about 0.1 kg.

Mass of a softball is about 0.2 kg.

Mass of a two litre carton of milk is about 2 kg.

Something that should be remembered when dealing with mass (or inertia) is that it is not the same as weight. Weight is a force, and is a vector quantity, having both magnitude and direction. Mass (or inertia) is not a force, and it is a scalar quantity, since it has magnitude, but not direction. Mass (or inertia) is the same regardless of the direction used in the measurement. In other words, the same tendency of a body to resist a change in its state of rest or of uniform motion will appear even though the direction of the unbalanced force changes. This difference between mass and force will be emphasized further in a later lesson when we learn more about the relationship between weight and mass.

QUESTIONS

1. What is an operational definition?

2. What is the difference between weight and mass?

3. What is the difference between volume and mass?

4. Is it possible for a body to have a much larger volume than another, but have a smaller mass? Explain this, giving an example.

5. A cargo handler in a space station works under the conditions known as weightlessness. There are several identical cartons floating in front of him; one of the cartons is full of gold bars, and the others are empty. How would he find the carton with the gold bars without opening the cartons? Use the operational definition of mass.

Lesson Summary

This lesson covered the following major topics.

Explanation of motion - Motion is described in the study of kinematics, and is explained in the study of dynamics. A satisfactory scientific explanation must have several features.

Familiar forces and units of force - Two kinds of forces with which most people are familiar are the forces of weight and friction. The newton, symbolized by N, is the unit of force often used in physics.

Forces as vector quantities - Forces have magnitude and direction, and hence are vector quantities. They can be represented by vector lines, and vector diagrams may be used to solve problems which involve finding the resultant of a group of forces acting on a body.

Newton's first law of motion.

Inertia and Mass - Mass is a measure of the inertia of a body. Operational definitions help to explain the meaning of words. The kilogram, symbolized kg, is the unit of mass often used in physics. Mass (or inertia) is not the same as weight.

End of Lesson 7

LESSON RECORD FORM

1260 Physics 10

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(3) Your work has been re-read to ensure accuracy in spelling and lesson details.
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NEWTON'S SECOND AND THIRD LAWS OF MOTION

Newton's Second Law of Motion

Read sections 5.8 and 5.9, pages 80-84 of the text.

Newton's First Law concerns bodies at rest or moving with constant velocities when there is no resultant force acting on the body. Newton's Second law, however, assumes that such a force is acting. Because of this force, there is change in motion of the body. From your everyday experience, you can visualize that if you are pushing a body and the body accelerates with an acceleration 'a', then the greater the push the greater the acceleration will be. You can say that acceleration is directly proportional to the force applied, which is the push in this case. Mathematically we can write,

$$\bar{a} \propto \bar{F}$$

Similarly you can visualize that if you apply the same push or force to a smaller mass it will accelerate more than if you apply the same push or force to a larger mass. Thus you can say that acceleration is inversely proportional to the mass of the body. Mathematically, we can write,

$$\bar{a} \propto \frac{1}{m}$$

Combining these two facts, you can write

$$\bar{a} \propto \frac{\bar{F}}{m}$$

or

$$\bar{a} = k\,\frac{\bar{F}}{m}$$

choosing proper units, so that $k = 1$,

$$a = \frac{\bar{F}}{m}$$

Thus the so-called 'force-equation' is obtained as

$$\bar{F} = m \cdot \bar{a}$$

Force = mass × acceleration

The most common unit of force is the newton. The newton is defined as the force that, applied to a 1 kg mass, will give it an acceleration of 1 m/s^2 i.e.

$$1\ N = 1\ kg \times 1\ m/s^2$$

SELF CHECK

Do questions 13-18, pages 84-85 of your text and check your answers with the answers given on page 148 of the text. You do not have to send these for correction.

13. State Newton's Second Law (a) in words (b) in equation form.

(a) ______________________________

____

____

(b) ______________________________

14. "Newton's second law holds only when frictional forces are ignored." True or false? Discuss.

____

____

____

____

____

____

15. The same unbalanced force is applied to bodies of masses 1 kg, 3 kg, 5 kg and 10 kg. If the acceleration produced on the first body is 15 m/s^2, what will be the accelerations of the other bodies?

16. To push a book at constant velocity along a table requires a constant applied force. What is the value of the net force on the book?

____

17. A net force of 10 N gives an object a constant acceleration of 4 m/s^2. What is the mass of the object?

18. A mass of 15 kg on a frictionless surface is given an acceleration of 3 m/s^2 by an applied force. What was the value of the force?

QUESTIONS

Attempt the following questions, write the answers in detail, and submit them for correction.

1. Why is the newton a derived unit rather than a fundamental unit?

____

____

____

____

____

2. How can you explain Newton's First Law in terms of Newton's Second Law?

Whenever the net force acting on a body is 0 (when the forces are balanced), there is no acceleration of the body. Therefore the body continues in its state of rest or uniform motion.

3. A moving cart is pushed from behind with a force of 10 N. The retarding forces of friction and air resistance equal 10 N. No other horizontal forces act on the cart. If it has a mass of 2 kg, what is its acceleration?

EXAMPLE 1

What will be the acceleration of a 1000 kg car if an unbalanced force of 800 N is applied?

Given: $F = 800\ \mathrm{N}$

$m = 1000\ \mathrm{kg}$

To find: a

Solution:

$$a = F/m = \frac{800\ \mathrm{N}}{1000\ \mathrm{kg}} = \frac{800\ \mathrm{kg\cdot m/s^2}}{1000\ \mathrm{kg}} = 0.8\ \mathrm{m/s^2}$$

EXAMPLE 2

A pony with a mass of 300 kg pulls a cart with a mass of 1000 kg. With what force will the pony have to pull on the cart if he is to accelerate at 2.0 m/s^2? Assume no friction in the wheels.

Note: The force on the cart accelerates the cart only, therefore the mass of the cart should be considered only.

Given: $m = 1000$ kg

$a = 2.0\ m/s^2$

To find: F

Solution: $F = m \cdot a$

$= 1000\ kg \times 2.0\ m/s^2$

$= 2000\ kg \cdot m/s^2$

$= 2 \times 10^3\ N$

PROBLEMS

Attempt the following problems and show your work.

1. A cart accelerates from rest to 6 m/s in 2 s. The force of friction is 5 N. If the cart is being pushed by an 11 N force, what is the mass of the cart?

$$\text{Remember } \bar{a} = \frac{\bar{v}_f - \bar{v}_i}{t}$$

2. A 1500 kg car moving at 15 m/s crashes into a wall and comes to a stop in 0.50 s. Assume that the acceleration of the car while stopping was uniform. Calculate the collision force in the crash.

3. A freight engine of mass 20 000 kg accelerates from rest to a velocity of 2.0 m/s in 5.0 s. If it is pulling a train of 20 cars each with a mass of 10 000 kg, what is the force in the coupling between the engine and the first car?

   (Note that the force in the coupling is exerted on the 20 cars. Therefore, the mass being accelerated **by that force** is the mass of the twenty cars.)

Newton's Third Law of Motion

Read section 5.10, pages 85-86 of your text.

When you hit a ball with a bat, the bat exerts a force on the ball. At the same time, the ball exerts a force on the bat. These two forces are equal in magnitude and opposite in direction.

This is an example of Newton's Third Law of Motion, which states that if one object applies a force to another, the second object applies an equal and opposite force to the first object. This law is most commonly stated as "For every action there is an equal and opposite reaction."

Weight and Mass

Read section 5.11, pages 87-89 of the text.

*Note: On pages 87 and 88 of the text weight is referred to as a scalar quantity. But in this course, as you must have learned in Lesson 7, we will be referring to weight as a vector quantity.

The inertia of an object provides a way of defining mass. The greater the mass of an object, the greater its tendency to keep at a constant velocity. Therefore mass is often defined as the quantitative measure of the inertia of an object.

Weight is the resultant of all the gravitational forces on an object. Weight is not a good physical standard; it varies from place to place. Mass on the other hand is constant, at ordinary velocities, even when moved from place to place.

Since force = mass × acceleration ($F = ma$) the weight of a body of mass, m, falling freely with an acceleration, a_g, will be

$$\overline{F}_g = m \times \overline{a}_g$$

One way of measuring weight is to suspend the body from a coiled spring, commonly called a spring balance. To measure mass, you can use an equal arm balance.

QUESTIONS

1. Name the reaction force to each of the following forces. Specify the object on which the reaction force acts.

   (a) A man holds up a book with his hand.
   (b) The earth exerts a gravitational force on the moon.
   (c) The north pole of a magnet exerts an attractive force on the south pole of another magnet.
   (d) A leaf falling to the ground pushes down on molecules of air.

   (a) ____________________

   (b) *The moon exerts a gravitational pull on the earth.*

   (c) ____________________

   ____

   (d) ____________________

   ____

2. A man is stranded near the centre of a frozen pond. Imagine that the pond surface is perfectly frictionless.

   (a) Could he walk to shore?
   (b) How would you suggest he could get to the shore?

   (a) __________

   (b) ____________________

   ____

   ____

3. A fishing line will break if it is subjected to more than 2000 N force. Will it break:

   (a) If an object weighing 2000 N is suspended from it?
   (b) If it is tied to a wall and pulled with a force of 2000 N?
   (c) If two men, one at each end, both pull on the line with a 2000 N force?

   (a) ____________________

   (b) ____________________

   (c) ____________________

4. (a) What is your mass expressed in kg?
   (b) What is your weight in N?

   (a) ____________________

   (b) ____________________

5. If all air could be removed from their paths, which would fall faster, a 10 kg steel ball or a 1 g feather? Explain why.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

6. A boy weighing 500 N standing on a bathroom scale jumps upward:

   (a) Explain why the pointer on the scale will point to more than 500 N the moment that he jumps upward.
   (b) What will happen to the pointer when he lands? Explain why.

   (a) ____________________

   ____

   ____

   ____

(b) *On contact with the scale the boy decelerates. Thus there is another force involved in addition to the boys weight. Thus the pointer will momentarily read more than 500 N.*

7. (a) A frictionless air puck with a mass of 10 kg is pulled on a level table with a force of 2 N. What would its acceleration be?

(b) Suppose that the same experiment were done on the moon. What would the acceleration of the air puck be? Why?

(a) ______________________________

____

____

(b) ______________________________

____

An Apparent Loss in Weight

Read section 5.12, pages 90-91 in your text. Note that the text uses a sign rule opposite to the more natural convention in which up is positive and down is negative.

In riding an elevator you sometimes feel lighter and at other times you feel heavier than usual. If you were standing on a weigh scale in the elevator, the reading on the scale would equal the magnitude of your apparent weight. Using simple formulas you can calculate your apparent weight in an elevator.

The net force on a body is equal to the vector sum of the forces acting on a body. The net force acting on you in an elevator is equal to the downward force of gravity plus the upward force exerted on you by the scale or by the floor of the elevator. This can be expressed as follows:

$$\vec{F}_{net} = \vec{F}_{gravity} + \vec{F}_{scale}$$

Solving for $\vec{F}_{scale}$, you find that

$$\vec{F}_{scale} = \vec{F}_{net} - \vec{F}_{gravity}$$

In applying the formulas above in problems you should make use of the facts that $\bar{F}_{net} = ma$, and $\bar{F}_{gravity} = ma_g$ (the weight). Remember that the magnitude of $\bar{F}_{scale}$ gives the apparent weight.

When the elevator moves with constant velocity, the formulas show that your apparent weight is the same as your actual weight.

$$\begin{aligned}\bar{F}_{scale} &= \bar{F}_{net} - \bar{F}_{gravity} = m\bar{a} - \bar{F}_{gravity} \\ &= 0 - \bar{F}_{gravity}, \text{ since } a = 0 \\ &= -m\bar{a}_g = -m\ (-9.8\ m/s^2)\end{aligned}$$

$F_{scale} = m\ 9.8\ m/s^2$ which is equal to (the magnitude of) your weight.

When the elevator accelerates upwards the formulas should tell you that you will feel heavier. Let's see.

$\bar{F}_{net}$ is positive since the net force on you is in the direction of your acceleration.

Here, $\bar{F}_{scale} = \bar{F}_{net} - m(-9.8\ m/s^2) = +\bar{F}_{net} + m\ 9.8\ m/s^2$.

From this you can see that F_{scales} is greater than $m\ 9.8\ m/s^2$. You should feel heavier, as expected.

When the elevator accelerates downwards $\bar{F}_{net}$ is negative and $\bar{F}_{scale} = -F_{net} + m\ 9.8\ m/s^2$. That is F_{scale} is less than $m\ 9.8\ m/s^2$ and you should feel lighter.

Now let us apply the methods used above to a concrete example.

EXAMPLE 3

A man weighing 6.0×10^2 N on earth is standing in an elevator on a weighing machine. Find the magnitude of his weight as recorded by the machine when

(a) the elevator moves downwards with a uniform speed of 4.0 m/s
(b) the elevator moves downwards with a uniform acceleration of 4.0 m/s²
(c) the elevator moves upwards with a uniform acceleration of 4.0 m/s²

Solution

(a) As the elevator is moving downwards with a uniform speed of 4.0 m/s, its acceleration is zero. Therefore the apparent weight of the man is the same as it is on earth i.e. 6.0×10^2 N

(b) Given: $\vec{a} = -4.0\ \text{m/s}^2$

$\vec{F}_{\text{gravity}} = -6.0 \times 10^2\ \text{N}$

To find: $\vec{F}_{\text{scale}}$

Solution: $m = \dfrac{\vec{F}_{\text{gravity}}}{a_g} = \dfrac{600\ \text{N}}{9.8\ \text{m/s}^2} = 61.2\ \text{kg}$

Apparent weight : $\vec{F}_{\text{scale}} = \vec{F}_{\text{net}} - \vec{F}_{\text{gravity}}$

Since elevator moves downwards with an acceleration, the acceleration will be negative.

$$
\begin{aligned}
&= +m\vec{a} - m\vec{a}_g \\
&= +61.2\ \text{kg}\ (-\ 4.0\ \text{m/s}^2) - (-\ 600\ \text{N}) \\
&= -\ 244.8\ \text{N} + 600\ \text{N} \\
&= +\ 3.5 \times 10^2\ \text{N}
\end{aligned}
$$

Magnitude of apparent weight $= 3.5 \times 10^2$ N.

(c) Given: $\vec{a} = +4.0\ \text{m/s}^2$

$\vec{F}_{\text{gravity}} = -6.0 \times 10^2\ \text{N}$

To Find: $\vec{F}_{\text{scale}}$

Since the elevator moves upwards with an acceleration, the acceleration will be positive.

Solution: $m = \dfrac{\vec{F}_{\text{gravity}}}{a_g} = \dfrac{600\ \text{N}}{9.8\ \text{m/s}^2} = 62.2\ \text{kg}$

Apparent weight : $\vec{F}_{\text{scale}} = \vec{F}_{\text{net}} - \vec{F}_{\text{gravity}}$

$$
\begin{aligned}
&= 62.2\ \text{kg}(4.0\ \text{m/s}^2) - (-600\ \text{N}) \\
&= 248.8\ \text{N} + 600\ \text{N} \\
&= +848.8\ \text{N} \\
&= +8.5 \times 10^2\ \text{N}
\end{aligned}
$$

Magnitude of apparent weight $= 8.5 \times 10^2$ N.

PROBLEMS

Attempt the following problems and show all the work.

1. An object of mass 2.0 kg is held on a string. What is the tension in the string (i.e. force exerted by the string on object), if:

   (a) The object is at rest?

   (b) The object is moving downward at 2.0 m/s?

   (c) The object is accelerating downward 2.0 m/s^2?

   (d) The object is accelerating upward at 2.0 m/s^2?

2. A 75 kg man stands in an elevator. (Hint: For the following you are looking for $\bar{F}_{scale}$).
   What force would the elevator exert on him, when:

   (a) the elevator starts moving upward with an acceleration of 1.5 m/s^2?

   (b) the elevator is moving upward with a constant speed of 2.0 m/s?

   (c) the elevator starts to accelerate downward at the rate of 1.5 m/s^2?

Lesson Summary

Newton's Second Law: An unbalanced force acting on an object produces an acceleration in the direction of the force. The acceleration varies directly as the force and inversely as the mass of the object i.e.

$$\vec{F} = m\vec{a}$$

Unit of force is newton. Newton is the force required to produce an acceleration of 1 m/s² in a body of mass 1 kg.

Newton's Third Law states that action and reaction are equal and opposite i.e. do not hit anybody hard as you will be equally hurt.

Weight of a body is equal to the magnitude of gravitational force acting on it i.e. $\vec{F}_g = m\vec{a}_g$

Apparent weight of a body in an elevator is less if the elevator accelerates downward, is more if the elevator accelerates upward and remains same if the elevator is moving with constant speed.

Solving for F_{scale} gives you the apparent weight.

$$\vec{F}_{scale} = \vec{F}_{net} - \vec{F}_{gravity}$$

PROBLEMS

Attempt the following problems and show your work.

1. A block of mass 2.0 kg is pulled on a frictionless table by a constant force of 6.0 N. The block starts from rest.

   (a) What is the acceleration of the block?

   (b) What is the speed of the block 3.0 s after the force starts acting?

   (c) How far does the block travel in 2.0 s?

2. A 6.0 kg object is acted upon by two forces of 3.0 N each.

(a) What is the net force if the forces act in the same direction?

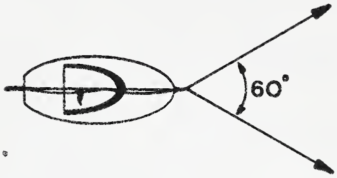
(b) What is the resulting acceleration for part (a)?

(c) What is the resulting force if the two forces act at an angle of 90° with each other?

(d) What is the resulting acceleration for part (c)?

3. Two men wish to pull a boat along a canal by means of a rope fastened near the front. If they use one rope, the boat will hit the side. To prevent this, they tie two ropes, each 12.0 m long, to the same point and stand on the ground 12.0 m apart when they pull.

   If each pulls with a force of 300 N, what is the force exerted on the boat? (This will be the resultant of the two forces.)



End of Lesson 8

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This lesson is a review lesson composed of questions which deal with many of the things covered in the first eight lessons of this course. Attempt to do the questions without referring to the earlier lessons until you come to something of which you are uncertain. Review the area about which you are unsure, and then try to complete the questions. By doing this lesson in that way, you will be able to get more benefit from it. You may wish to go ahead with Lessons 10, 11, and 12 while waiting for previous lessons to return.

MULTIPLE CHOICE QUESTIONS

1. A biophysicist is concerned with intereactions between

   (a) energy and matter.
   (b) radiation and human tissues.
   (c) heat and energy.
   (d) electricity and magnetism. ______

2. Which of the following statements is False.

   (a) According to Aristotle celestial bodies have the same composition as the bodies on the Earth.
   (b) According to Aristotle, heavenly bodies moved in perfect circles around the Earth.
   (c) Aristotle's major works were in the fields of politics and philosophy.
   (d) According to Aristotle a 25 kg stone will fall faster than a 20 kg stone. ______

3. Who is called "the father of the modern science"?

   (a) Aristotle
   (b) Galileo Galilei
   (c) Democritus
   (d) Einstein ______

4. Which of the following pairs have the same conversion factor?

   (a) kg to g and mg to g
   (b) m to cm and cm to mm
   (c) L to mL and kg to g
   (d) h to min and s to min ______

5. Peggy tries to approximate the interaction between the π-meson and the deuteron by equations. She then uses a computer to test the effect of the assumptions. Peggy will be called

   (a) an experimental physicist.
   (b) a geophysicist.
   (c) a biophysicist.
   (d) a theoretical physicist. ______

6. According to Aristotle, which of the four elements had the highest place?

   (a) Earth
   (b) Water
   (c) Air
   (d) Fire

7. Which of the following numbers has the same number of significant digits as 0.002 50?

   (a) 2.5×10^2
   (b) 847.4
   (c) 0.000 23
   (d) 7.50

8. How many significant digits may be indicated in the sum of 0.09, 5.231, 2.1 and 4.61?

   (a) 1
   (b) 2
   (c) 3
   (d) 4

9. A bus travels a distance of 260 km from 08 15 o'clock to 11 30 o'clock. At this point it stops for half an hour and then travels an additional 370 km completing its journey at 16 00 o'clock. The average speed of the bus for the entire time it was in motion was

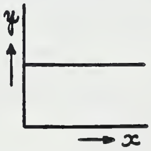
   (a) 86 km/h
   (b) 87 km/h
   (c) 80 km/h
   (d) 92 km/h

10. Which of the following statements about SI units is FALSE?

   (a) A zero is always used before a decimal marker, if the unit is less than one.
   (b) Symbols are never pluralized.
   (c) Symbols should be preferably used in place of unit names.
   (d) Decimals and fractions are equally acceptable.

11. Which of the following statements is TRUE for the line shown?

   (a) The slope of the line is undefined.
   (b) The slope of the line is zero.
   (c) The slope of the line is positive.
   (d) The slope of the line is negative.



12. The unit of force in the metric system is

(a) gram.
(b) kilogram.
(c) newton.
(d) dyne. ________

13. When a body is moving at a constant speed in a straight line,

(a) there are no forces acting on it.
(b) the forces acting on it are not in contact with it.
(c) the body is in vacuum.
(d) the forces acting on it are balanced. ________

14. A stone is dropped from a height of 490 m. What is its speed when it reaches the ground?

(a) 9.8 m/s
(b) 98 m/s
(c) 49 m/s
(d) Not sufficient data given. ________

15. A car starting from rest undergoes a uniform acceleration of 2.00 m/s^2. The final speed of the car after 10.0 s will be

(a) 2.00 m/s
(b) 10.0 m/s
(c) 20.0 m/s
(d) 40.0 m/s ________

16. A car was cruising at 60.0 km/h when the brakes were applied suddenly and the car was stopped in 10.0 s. The acceleration of the car will be

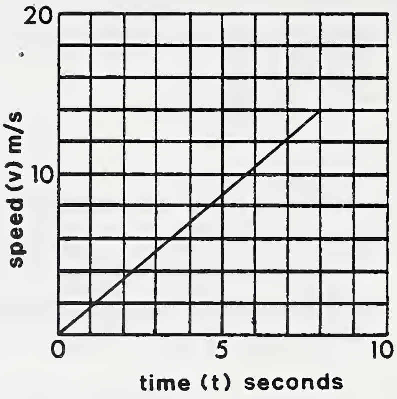
(a) 6.00 km/h^2
(b) -6.00 km/h^2
(c) 16.7 m/s^2
(d) -1.67 m/s^2 ________

17. Which of the following statements is FALSE?

(a) A body moving with a uniform velocity will have zero acceleration.
(b) Direction has nothing to do with acceleration of a body.
(c) Acceleration is the slope of a velocity-time graph for a body moving with uniform acceleration.
(d) Area under the line in a speed-time graph gives the distance travelled by a body. ________

18. The speed-time graph for a body is shown. The distance travelled by the body in 7.0 s will be

    (a) 112 m
    (b) 84 m
    (c) 42 m
    (d) 56 m



______

19. What were the four elements according to Aristotle?

    (a) earth, fire, oxygen and water
    (b) earth, air, water and energy
    (c) carbon, oxygen, hydrogen and nitrogen
    (d) earth, fire, water and air ______

20. Which of the following represents the definition of acceleration that Galileo chose to use?

    (a) $\frac{\Delta d}{\Delta t}$

    (b) $\frac{v_f}{t}$

    (c) $\frac{\Delta v}{\Delta t}$

    (d) $\frac{1}{2}at^2$ ______

21. Why could not Galileo test his hypothesis about falling bodies directly?

    (a) He did not have an accurate and commonly accepted unit of distance.
    (b) He did not have a proper laboratory in which to work.
    (c) The cost of conducting such an experiment would have been prohibitive for the time.
    (d) He had no way of measuring the time accurately. ______

22. In his investigations of motion Galileo suggested at one point that all bodies fall at the same rate of acceleration no matter what their size. Which of the following steps of scientific investigation was Galileo doing in making this suggestion?

(a) choosing a definition
(b) stating an assumption
(c) deducing predictions from the assumptions or hypothesis
(d) testing the predictions by experiment ______

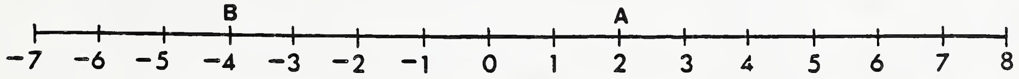
23. When the term "aether" is used in physics, what does it refer to usually?

(a) A substance that fills space, and which may be used to define absolute motion or rest.
(b) A substance that can be used to put animals and people to sleep.
(c) A choice, such as aether this or that.
(d) A gas which can be used to propel rockets through space. ______

24. Which one of the following is a vector quantity?

(a) Speed
(b) Time
(c) Displacement
(d) North ______

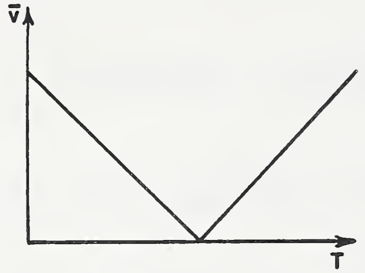
25. According to the following number line, what is the displacement of a body at point B with respect to point A?



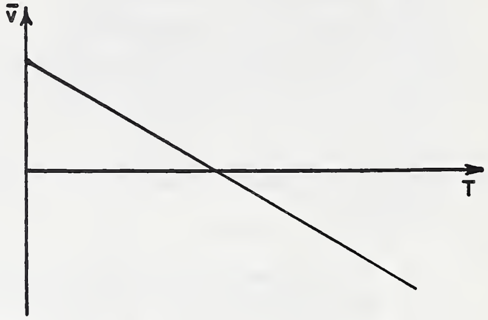
(a) 2
(b) -2
(c) -4
(d) -6 ______

26. A ball thrown vertically into the air rises freely and then falls freely back to the thrower. Which one of the following velocity-time graphs describes the motion of the ball while it is in flight through the air? Consider $\overline{v}$ is positive upwards.

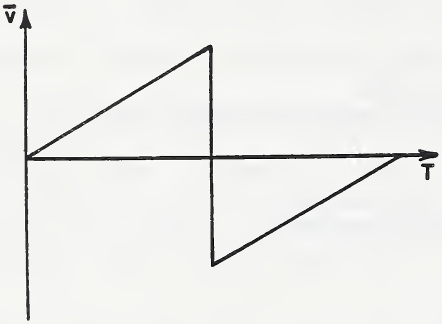
(a)



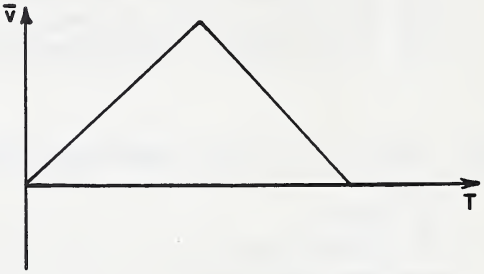
(b)



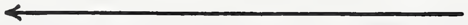
(c)



(d)



27. The following vector line represents a displacement of 28.0 m west.



What scale was used to draw the line?

(a) 1.0 cm = 4.0 m
(b) 1.0 cm = 7.0 m
(c) 4.0 mm = 7.0 m
(d) 10 mm = 28.0 m

28. In physics, the term "dynamics" refers to

(a) the study of such things as velocity, acceleration, speed, and displacement.
(b) the study of such things as force, mass, and momentum.
(c) the study of such things as dynamos and dynamometers.
(d) a condition that is opposite to stationary (static).

29. What does the term "unbalanced force" mean?

(a) The tendency for a body to topple and fall.
(b) The force that must be overcome in order to keep a body balanced.
(c) The force acting on a body when it is in stable equilibrium.
(d) The non-zero resultant of a group of forces acting on a body.

______

30. Which of the following statements would be a possible re-statement of Newton's first law of motion?

(a) A body tends to resist any change in velocity.
(b) A body at rest remains that way unless acted upon by a force; once in motion, it can continue moving only as long as the force is applied.
(c) A body at rest or moving with constant acceleration continues in that state unless acted upon by an unbalanced force.
(d) The acceleration of a body varies directly as the applied force.

______

31. How do mass and inertia differ?

(a) Mass is a measure of the property of inertia of a body.
(b) Mass refers to a state of rest; inertia refers to a state of motion.
(c) Mass refers to a state of motion; inertia refers to a state of rest.
(d) Mass refers to weight; inertia refers to the difficulty experienced in pushing a body.

______

32. In physics, an operational definition refers to

(a) a description of the mathematical operations needed in defining a physical law.
(b) an operation which has a high level of kinematic definition.
(c) a description of an activity used to explain a word.
(d) a definition of a word found in Newton's Physical Operations Dictionary.

______

33. What is the symbol of the unit of mass commonly used in physics?

(a) N
(b) M
(c) kg
(d) m

______

34. How does mass differ from force?

(a) They do not differ; mass is a special kind of force.
(b) Mass is a scalar quantity; force is a vector quantity.
(c) Mass is a vector quantity; force is a scalar quantity.
(d) Mass refers to the volume of a body; force refers to the weight of a body. ______

35. What unbalanced force acting on a 2 kg mass for 2.0 s will impart to it a velocity of 20 m/s?

(a) 10 N
(b) 20 N
(c) 5 N
(d) 80 N ______

36. An elevator moves downwards with an acceleration of 4.00 m/s^2. It is fully loaded and is carrying a mass of 2.00×10^3 kg. The apparent weight of the load will be

(a) 1.96×10^4 N
(b) 8.00×10^3 N
(c) 2.76×10^4 N
(d) 1.16×10^4 N ______

37. A man is standing in an elevator which is moving downward with a constant acceleration of 2.0 m/s^2. The man will

(a) feel the same weight as on earth.
(b) feel as if he has lost weight.
(c) feel as if he has gained weight.
(d) not feel any weight at all. ______

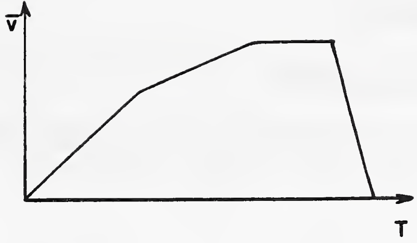
38. A ball is thrown upward with an initial speed of 20.0 m/s. What is its velocity 3.0 s after being thrown? (Assume air resistance is negligible.)

(a) 0
(b) 9.4 m/s down
(c) 28.4 m/s up
(d) 28.4 m/s down ______

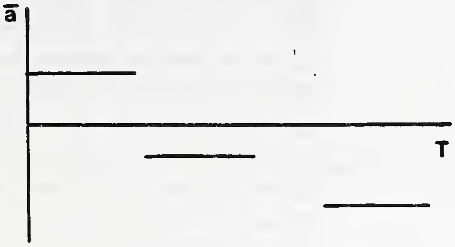
39. In determining the mass of a body, it is important to consider

(a) the amount of space it takes up.
(b) the position of the body with respect to the center of the earth.
(c) the amount of resistance to a change in its velocity.
(d) the size of the friction force it exerts on a smooth surface compared to a rough surface. ______

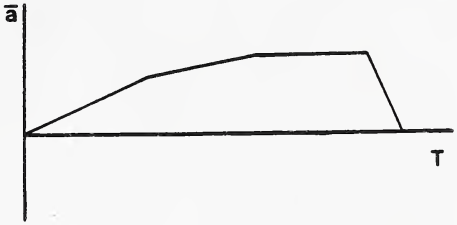
40. A velocity-time graph is shown to the right. Which one of the following acceleration-time graphs would refer to the same motion?



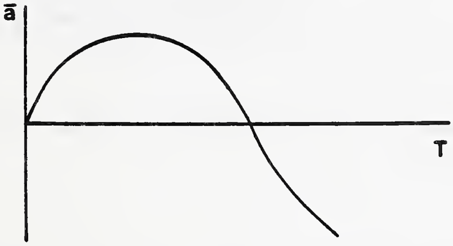
(a)



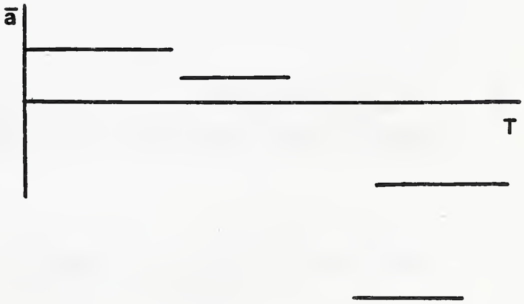
(b)



(c)



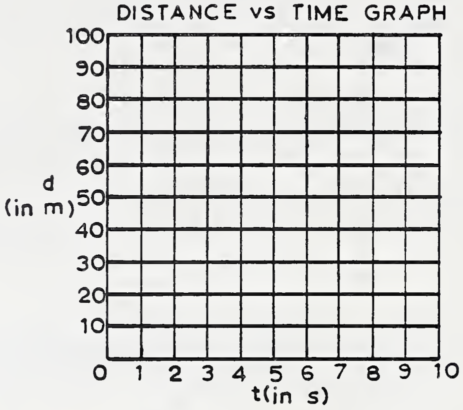
(d)



Before going on, mark your answers using the key on page 16. If you cannot figure out how a given answer is obtained ask about it on page 16. Be sure to indicate clearly that you have marked each question.

PROBLEMS

1. Draw a distance-time graph representing an object travelling in uniform motion at a speed of 10 m/s.



2. A body covers 50.0 cm in 10.0 s and 75 cm in 15.0 s. What will be distance (km) travelled by it in 1.0 h?

3. A plane travelling at 200 km/h accelerates at 5.0 (km/h)/s for 1.0 min. What will be its final speed at the end of the given time period?

4. A body is thrown vertically upwards with a speed of 20.0 m/s.

   (a) What will be the speed of the body when it is at the highest point?

   ____

   (b) How high will it go?

5. A ball is thrown vertically down from a window at 10.0 m/s and hits the ground in 5.0 s. What is the height of the window?

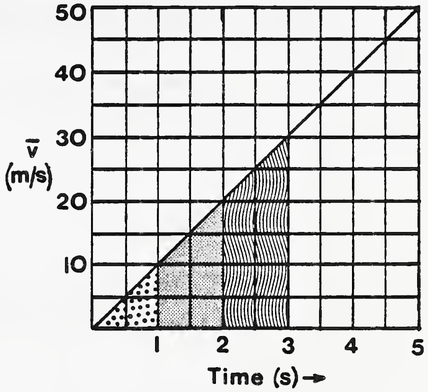
6. An object falls 40 m from a high building.

(a) How long does it take to fall the first half of the distance?

(b) What is its velocity at this point?

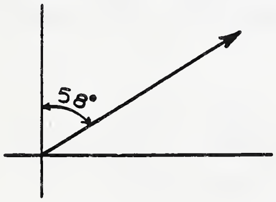
(c) How long does it take to fall the second half of the distance?

7. Show from a speed-time graph that the distances travelled in successive equal time intervals by a body accelerating uniformly from rest are in the ratio 1:3:5:7 ... (Hint. Recall that the area under the line on a speed-time graph for a certain time-interval equals the distance travelled in that interval. Start by finding the areas of the three regions shown under the graph).



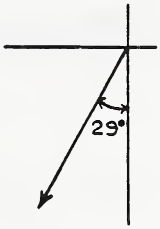
8. Using the convention involving the directions cross, give the directions of the following vector lines.

(a)



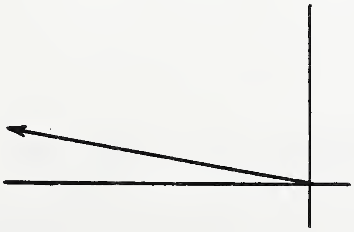
Direction 58° E of N

(b)



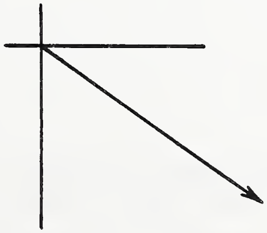
Direction 29° W of S

(c)



Direction ____________

(d)



Direction ____________

9. A man at the edge of a cliff 18.0 m above the floor of a canyon tosses a rock to a height of 12.0 m above the level of the cliff. The rock then falls to the floor of the canyon. Assume that the rock moves freely through the air ($a_g = -9.8\ m/s^2$).

(a) What is the velocity of the rock 12.0 m above the cliff?

____

(b) What is the velocity of the rock 7.0 m above the cliff when the rock is falling? ____________________

(c) What is the velocity of the rock 7.0 m above the cliff when the rock is rising? ____________________

(d) What is the velocity of the rock at the level of the cliff when it is falling? ____________________

10. A car moves to point A 25.0 km east of a house, and then moves 65.0 km west of point A.

(a) What is its displacement with respect to the house?

____

(b) What is the total distance that the car moves?

____

11. An 8.0 kg object is acted upon by two fores, 3.0 N due east and 4.0 N due north.

(a) What is the resultant force?

(b) What is the direction and magnitude of the acceleration?

12. Draw a vector diagram to find the resultant of the following group of forces acting through the same point of a body.

17.0 N east
22.0 N 30° west of south
14.0 N north
9.0 N west

Answers to Multiple Choice Questions on pages 1-9

1. b
2. a
3. b
4. c
5. d
6. d
7. d
8. c
9. b
10. d
11. b
12. c
13. d
14. b
15. c
16. d
17. b
18. c
19. d
20. c
21. d
22. b or c
23. a
24. c
25. d
26. b
27. a
28. b
29. d
30. a
31. a
32. c
33. c
34. b
35. b
36. d
37. b
38. b
39. c
40. d

Any questions?

End of Lesson 9

N.L.C. - B.N.C.
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